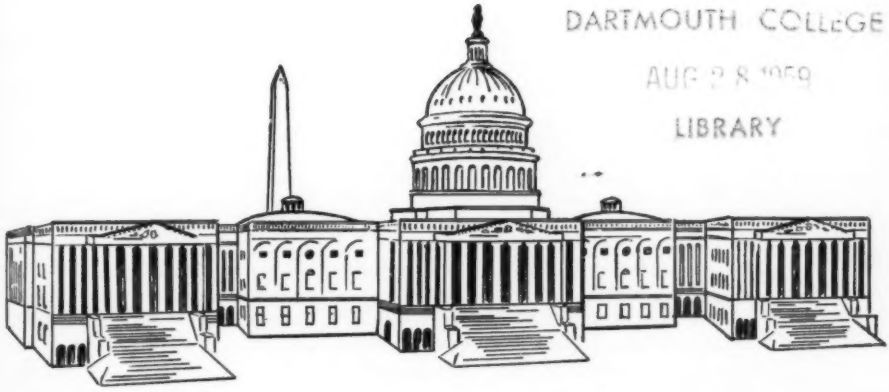
506
g W277j

VOLUME 49 *July 1959* NUMBER 7

JOURNAL

OF THE

WASHINGTON ACADEMY OF SCIENCES



DARTMOUTH COLLEGE
AUG 2 8 1959
LIBRARY

Published Monthly by the

WASHINGTON ACADEMY OF SCIENCES

1530 P STREET, N.W., WASHINGTON 5, D.C.

Journal of the Washington Academy of Sciences

Editor: CHESTER H. PAGE, National Bureau of Standards

Associate Editors: RONALD BAMFORD, University of Maryland
HOWARD W. BOND, National Institutes of Health
IMMANUEL ESTERMANN, Office of Naval Research

This JOURNAL, the official organ of the Washington Academy of Sciences, publishes: (1) Original papers, written or communicated by members of the Academy; (2) proceedings and programs of meetings of the Academy and affiliated societies; (3) correspondence of interest to Academy members; and (4) notes of events connected with the scientific life of Washington. The JOURNAL is issued monthly. Volumes correspond to calendar years.

Manuscripts should be sent to the Editor. It is urgently requested that contributors consult the latest numbers of the JOURNAL and conform their manuscripts to the usage found there as regards arrangement of title, subheads, synonymies, footnotes, tables, bibliography, legends for illustrations, and other matter. Manuscripts should be typewritten, double-spaced, on good paper. Footnotes should be numbered serially in pencil and submitted on a separate sheet. The editors do not assume responsibility for the ideas expressed by the author, nor can they undertake to correct other than obvious minor errors.

Proof.—In order to facilitate prompt publication one proof will generally be sent to authors in or near Washington. It is urged that manuscript be submitted in final form; the editors will exercise due care in seeing that copy is followed.

Reprints of papers are available to nonmember authors at the price of $1.50 per page per hundred reprints, plus $1.50 per hundred for handling charge. Authors who are Academy members are entitled to a 33⅓ percent discount. For more than 200 reprints of a single paper, the additional hundreds are furnished at half the above rate. Short papers are subject to a minimum reprint charge of $5 per hundred for the first 200, and $2.50 per additional hundred. Covers are subject to a uniform price of $7.50 for the first hundred; $2 per additional hundred. All authors have the option of purchasing complete journal copies for approximately 10 cents each.

Publication Charges—Authors' institutions are requested to honor a publication charge of $15 per page to partially defray actual cost. When these charges are honored, the first hundred reprints are free, and a special credit of $5 per page is allowed against unusual typographical costs.

Unusual costs occasioned by foreign, mathematical, or tabular material, or excessive illustrations, as well as alterations made in proof by the author, may be charged to the author. The Academy pays the first $10 of extra cost for a member author.

Subscription Rates for the JOURNAL.—Per Year $7.50

Price of back numbers and volumes:	*Per Vol.*	*Per Number*
Vol. 1 to vol. 10, incl.—not available*	—	—
Vol. 11 to vol. 15, incl. (21 numbers per vol.)	$10.00	$0.70
Vol. 16 to vol. 22, incl. (21 numbers per vol.)	8.00	0.60
Vol. 23 to current vol. (12 numbers per vol.)	7.50	0.90

* Limited number of complete sets of the JOURNAL (vol. 1 to 48, incl.) available for sale to libraries at $401.00.

MONOGRAPH No. 1, "The Parasitic Cuckoos of Africa," by Herbert Friedmann $4.50

MONOGRAPH No. 2, "Microsomal Particles and Protein Synthesis" (symposium) (order from Pergamon Press, 122 East 55th Street, New York 22, N. Y.) ... $5.00

INDEX TO JOURNAL (vols. 1–40) and PROCEEDINGS $7.50

PROCEEDINGS, vols. 1–13 (1899–1911) complete $25.00
Single volumes, unbound 2.00
Single numbers ..... Prices on request

Missing Numbers will be replaced without charge provided that claim is made to the Treasurer within 30 days after date of following issue.

Remittances should be made payable to "Washington Academy of Sciences" and sent to the Treasurer, Washington Academy of Sciences, 1530 P Street, N.W., Washington 5, D. C.

Changes of Address, Subscriptions and requests for back numbers should be sent to WASHINGTON ACADEMY OF SCIENCES, 1530 P Street, N.W., Washington 5, D. C.

Second class postage paid at Baltimore, Md.
Acceptance for mailing at a special rate of postage provided for in the Act of February 28, 1925.
Authorized February 17, 1949.

JOURNAL
OF THE
WASHINGTON ACADEMY OF SCIENCES

VOL. 49 JULY 1959 No. 7

SYMPOSIUM ON THE HISTORY OF AMERICAN GEOLOGY

* * *

Prefactory Statement

The papers published in this issue of the JOURNAL were presented as a part of a Symposium on the History of American Geology at the Washington meeting of the American Association for the Advancement of Science, December 27 and 28, 1958. The Symposium was arranged by Edgar W. Owen, of the University of Texas, and was sponsored jointly by AAAS Section E (Geology and Geography), Section L (History and Philosophy of Science), and the Geological Society of America.

The Symposium aimed to examine the current state of investigation into the history of the science and its applications and to stimulate interest in the subject. Of the 224 American colleges giving majors in geology, only 18 offer courses in the history of geology. The scarcity of historical publications during the period when the science has undergone phenomenal development of its basic concepts and practical applications indicate the existence of a fertile field for mature and discriminating research.

The following papers, not made available for inclusion here, were also presented at the Symposium:

DIRK J. STRUIK, Massachusetts Institute of Technology: *Science in America before 1830.* Published in Science, April 24, 1959.

KIRTLEY F. MATHER, Harvard University: *Geology, geologists, and the AAAS.* Published in Science, April 24, 1959.

F. C. MACKNIGHT, University of Pittsburgh: *A university course in history of geology for seniors and graduates.*

ERWIN F. LANGE, Portland (Oregon) State College: *Dr. John Evans, U. S. geologist to the Oregon and Washington Territories.* Published by American Philosophical Society, 1959.

HERMAN R. FRIIS, National Archives: *Highlights in the history of the development and use of topographic maps as a base for delineating geological information by agencies of the Federal Government, 1800–1879.*

Notes on the Earliest Geological Maps of the United States, 1756–1832

By JOHN W. WELLS, *Cornell University*

Here I propose to consider briefly a still poorly understood aspect of American geology, that of the earliest geological maps. Published listings and accounts of these early maps are very few, and all are incomplete. The best are Jules Marcou's *Mapoteca geologica Americana* (1884) and Ireland's *History of the development of geologic maps* (1943). Important also is Leighton's *One hundred years of New York State geologic maps* (1910). There are a few notices of early maps in Merrill's *Contributions to the history of American geology* (1906). Stanton's *Evolution of the geologic map of the United States* (1934) mentions only two maps prior to 1843 (Maclure's maps of 1809 and 1817). At least 11 maps are known that show the geology of this country as it then was understood before 1843.

It is assumed that there is agreement on the essential characteristics of a geological map as contrasted with other types of maps. They are attempts to show symbolically the distribution of the different kinds of rock at or near the earth's surface. Thus, Lewis Evans's maps of 1749, 1751, and 1755 can not be considered as geological, although his *Analysis* of 1755 indicates that he could have produced a most creditable one.

In 1756, however, a genuine geological map of America appeared in France. This was in a memoir on the mineralogical comparison of Canada and Switzerland by the great French naturalist Jean-Étienne Guettard, who had never been in North America. This map has generally been dismissed as merely showing by various symbols the localities of some 39 kinds of "earths," rocks, minerals, and fossils, but it is truly a geological map, for like all geological maps it exhibits a generalization of the distribution of the rocks. By even modest standards it is a poor map, and while it is probable, as White (1951) has suggested, that Lewis Evans could have produced a better one based on extensive first-hand knowledge, he did not, and Guettard's effort must stand as the oldest geological map of the continent as well as one of the oldest of geological maps in general. It was as good in its time as many of the later ones, but unlike many of them it was almost wholly ignored, was never a source of information, and had not their wider distribution, especially in the land to which it referred. An English version appeared in the Literary Magazine, or Universal Review in 1757, which was reprinted later in Fuller's *Naval Chronicle* (1760) (Ireland, 1943, p. 1257).

Guettard's map developed from a memoir he read before the Académie Royale des Sciences in Paris in 1752, a date often quoted as its publication date. First based largely on information in Charlevoix's *Historie et déscription génèrale de la Nouvelle France*, it was considerably augmented by the time it was first published in 1756; Comte de la Galissionère and M. Gautier, the latter King's Physician at Quebec, had in the meantime sent him specimens and notes. He may also have gotten some information from the *Jesuit Relations*. Guettard undertook the compilation from a desire to see if other countries showed the same systematic arrangement of rocks, minerals, and fossils that he had already made out for France, where he recognized three *terreins* or *bandes*. He thought he demonstrated this for Canada and Switzerland, and marked the extent of the *bandes* on his maps. He suggested that they could be traced into Mexico and into Greenland, and thereby be linked to their counterparts in England, probably the earliest attempt at intercontinental correlation. The first of his *bandes* was the *Bande Sableuse*: sands, marls, and sandstones that extended along the continental shelf from the Gulf of Mexico to Newfoundland and the Grand Banks. The *Bande Marneuse*, with limestones with no other metal than iron, is shown along the Gulf and Atlantic Coastal Plains, including eastern New York,

New England, and eastern Quebec. The *Bande Schisteuse ou Métallique*, with shales, slates, sandstone, coal, marble, granite, etc., with many metals and hot springs but few fossils, covered all the continent then known westward from the *Bande Marneuse*, including the Maritime Provinces. On the map these three *Bandes* are labeled by name and the middle one is shaded.

Guettard regarded fossils as important, especially is showing the geological similarities of one continent with another. It may be noted is passing that the first figures of American Paleozoic (Ordovician) fossils appeared in his memoir.

This first attempt to map the geology of America and correlate it with Europe, based upon what were later developed anew as working principles when Wernerian concepts failed, deserves the premier place in the history of American geology in ways other than merely chronological.

Some 40 years later, Constantin-François Chasseboeuf, later Comte de Volney, traveled extensively for several years in the United States, and in 1803 he published his then famous but now almost forgotten *Tableau du climat et du sol des États-Unis d'Amérique*, an attempt to assess the relation of the soil and climate to the economy, politics, and viability of the new Republic. A year later two englished versions appeared in London and Philadelphia which have been the source of most references to Volney's geology. There were several later editions in French, one in German, and one in Italian. It is curious that this work should be so little known today, for it first brought an idea of American geology widely to the notice of Europeans.

Volney's ideas on American geology were not wholly original. His classification of the rocks was derived from that of Samuel L. Mitchill (1798–1802), who in turn owed much to Lewis Evans. He recognized five regions, each characterized by certain types of rocks: (1) a *Granitic region*, from Long Island to the mouth of the St. Lawrence and the Thousand Islands, separated by the Mohawk Valley from (2) the *Catskill Sandstone region* (Les grès de Katskill), extending west of the Hudson Valley as far as the "Genesee lakes," (3) a *Limestone region* in the "West or Back country," (4) marine sands of the coastal plain, and (5) the [Piedmont] region between the fall-line ("sillon d'isinglass," a term first used by Lewis Evans) and the sandstone or granite mountains.

An anonymous review, probably by Mitchill, of Volney's book appeared in that fascinating *omnium gatherum* of doings in American science, the Medical Repository, in 1804–05. It noted that Volney's terrains corresponded to Mitchill's, and that Volney "possesses a discriminating as well as generalizing mind" and "beheld with an observing eye the tracts over which he travelled" (p. 189). The geological eye-opener to the reviewer, however, was Volney's geologically colored map: "This is a beautiful and obvious manner of expressing the prevalence of any of the great strata of the earth, as over-spreading or underlaying [*sic*] an extensive tract of country. It is a pity that map-makers have not more generally observed it" (p. 411).

This appears to be the first and only published reference to the important fact that Volney's map, to us misleadingly titled *Carte des États-Unis de l'Amérique-Nord, pour servir au tableau du climat et du sol par C. F. Volney* (40 × 53 cm, lacking any geological legend), was geologically colored. And indeed in very few copies of the original French edition and in none of the later editions is the map colored, although all have geological indications such as the trace of the outcrop of the "Isinglass Vein" and the "Limestone Band" in Virginia. The only colored copy I have yet seen is William Maclure's large-paper copy which is now in the library of the Academy of Natural Sciences of Philadelphia, a small portion of which is shown in Fig. 1. But that the map was to be colored has always been obvious from this note printed on the *errata* page (p. 534) of the 1803 edition:

Avis au Lecteur

Dans la grande Carte qui est coloriée, le sol *calcaire* est designée par la couleur *verte*; le *granitique*, par la couleur *rouge*; et le *grès*, par le *bistre*; et dans la petite carte [climatic] l'*orange* marque le lit du vent; le *verd-d'eau*, indique le courant du Golfe.

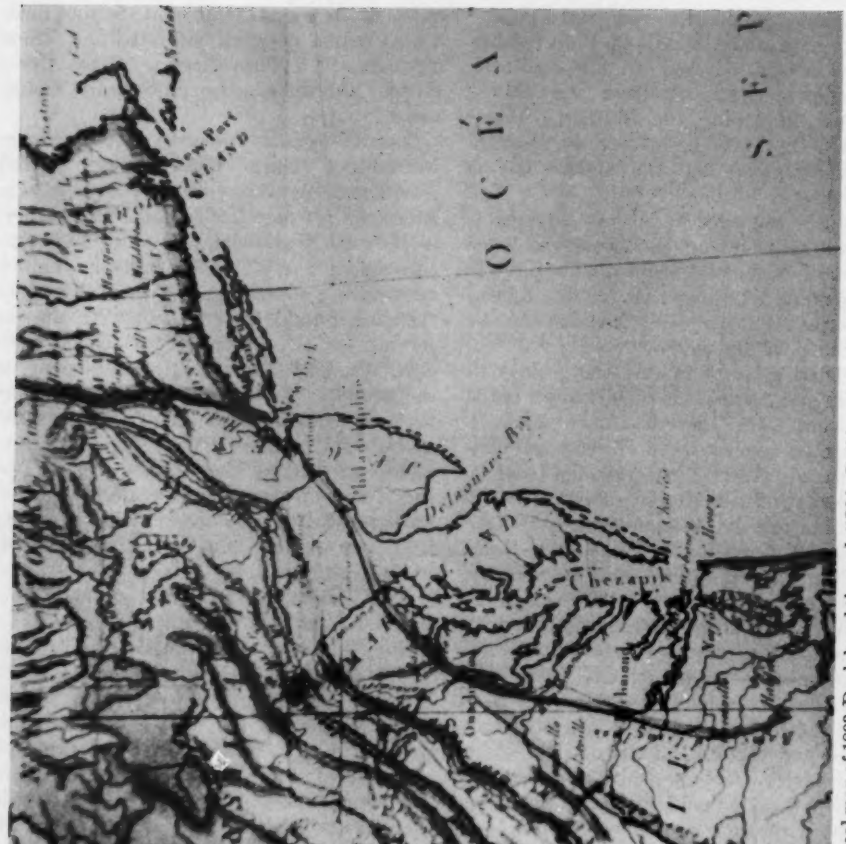


FIG. 1.—Part of Volney's geological map of 1803. Dark band through "Ohio R." is green, the limestone terrain; dark area southwest from the "York" of New York is bistre, the Catskill sandstone terrain; and the dark stripes in the Appalachians, the coastal plain, and the New England coast are red, the granitic terrain. (From copy in Acad. Nat. Sci. Philadelphia, × 1).

This extraordinary synthesis, the second geological map of the United States and one of the very earliest of published colored geological maps, surely deserves as much respect as Maclure's attempt six years later.

A parenthetical note may be added here: Volney, who had visited Thomas Jefferson several times at Monticello, sent him a copy of the *Tableau*. Jefferson acknowledged it early in 1805 in a lengthy letter (Chinard, 1923, p. 171–175), in the course of which he sniffed at the geological part:

> Of the first [geological] part I am less a judge than most people ... [not] having indulged myself in geological inquiries, from a belief that the skin-deep scratches which we can make or find in the surface of the earth, do not repay our time with as certain and useful deductions as our pursuits in some other branches.

So much for geology from the first of democrats!

The year 1809 is, of course, memorable for the appearance of William Maclure's map of the United States. While this is only the third, it is the earliest well-known geological map of this country, and Maclure has been overpraised as the "father of American geology" and the "William Smith of America." Many have taken his memoir and map as the starting point of our geology. Maclure introduced the Wernerian classification to American geology, a classification that was to dominate as well as to hinder its progress for two decades. Although Maclure certainly made observations in much of the country east of the Alleghenies, he was obviously greatly indebted—an unacknowledged debt[1]—to the published details and observations made earlier by Evans, Schoepf, Larochefoucauld-Liancourt, Mitchill, and especially to Volney as evidenced by the geological coloring of his map. His classification was hardly more than Mitchill's put in Wernerian terminology; and his almost total disregard of fossil evidence scarcely warrants his being placed even near William Smith. But his map was good, the best of its time considering the large area covered, especially since it reputedly represented the results of little more than a year's work. In 1809 Mitchill noted Maclure's forthcoming map in the Medical Repository and mentioned that Maclure had returned to the United States in 1808 (others say 1807) after 9 or 10 years in Europe (where he had been an agent of the United States government), that he had started working on American geology in the summer of that year, and that he had already delineated the principal strata on a map. It is entirely likely that Maclure already had his map outlined before he returned to this country and went into the field. Two bits of evidence suggest this. One is the sour comment of Gilbert Chinard (1923, p. 101, footnote) to the effect that Maclure, who had been in Paris in 1801 on affairs of the American government, obtained much unacknowledged information from Volney:

> Maclure fit autre chose que de recueillir des observations pour le compte du gouvernement américain; il receuillit auprès de Volney les matériaux pour ses *Observations on the geology of the United States....*, et qui lui ont value la réputation d'être l'auteur de la première étude géologique sérieuse sur les Etats-Unis, ...

The second is found in the second version of Maclure's map, published in the Journal de Physique in Paris in 1811. This map was prepared in France from a colored map that Maclure had sent to J.-C. Delamétherie, editor of the Journal in 1809 together with his memoir. As published this map has the same color scheme as the 1809 map, colors different from those on the map sent to Paris. Most remarkable, however, is that the base map is Volney's 1803 map, with re-engraved title but retaining all other details including Volney's route trace and contact lines. Either Maclure sent Delamétherie a copy of Volney's map with his own geological coloring, or Delamétherie had Maclure's data transferred to pulls from the re-engraved plate of Volney's map. Also, the curious caterpillar bands of granitic or primary color in Canada, found on Volney's map but not on Maclure's 1809 map in the Transactions of the American Philosophical

[1] Maclure rarely referred to the work of others. His theory of the origin of the secondary rocks of the Mississippi basin in a vast inland sea or lake impounded behind the Appalachians, solemnly advanced so late as 1823, makes no mention of the fact that this had been previously elaborated by Mitchell and Volney, and according to White (1951) the idea can be traced back to Lewis Evans.

FIG. 2.—Geological map from Hinton's *History and topography of the United States*, 1832, × 2/5. Geology east of the Mississippi from Maclure; west of the Mississippi to the Chippewayan (Rocky) Mountains based on James.

Society, appear on the 1811 version. Were they added by Delamétherie from Volney's map or were they on the map Maclure sent Delamétherie?

A version of Maclure's map that has generally been overlooked, except by Marcou (1893, p. 6), appears in L. A. F. de Beaujeur's *Aperçu des États-Unis* . . . , published in Paris in 1814 and englished the same year by William Walton. This is colored in Wernerian fashion only along the contact lines, and admittedly is based wholly on Maclure.

Two other versions of the Maclurean map appeared in the two editions of Parker Cleaveland's *Elementary treatise on mineralogy and geology*, 1816 and 1822. They were no improvement on Maclure and scarcely warrent mention except for their wide circulation of Maclure's work.

In 1817 and 1818 Maclure published revised editions of his memoir and map. The 1817 edition appeared as a book in Philadelphia; that of 1818 was published in the Transactions of the American Philosophical Society. The geology on both is essentially the same and these maps are generally listed as if they were the same. They were printed, however, on different bases and only the 1818 issue carries a geological legend. Geological details on both are only a slight improvement over the 1809 map. The base maps for both were very poor for the time. In a critical notice of Maclure's memoir and map of 1817 Rafinesque clearly pointed out the path to be followed:

> . . . We must especially collect and describe all the organic remains of our soil, if we ever want to speculate with the smallest degree of probability on the formation, respective age, and history of our earth. (1818, p. 43).

The eleventh and last map (Fig. 2) considered here is almost completely unknown, except for listing in two catalogues of the Library of Congress and mention by Ireland (1943, p. 1260). It appeared in John Howard Hinton's *History and topography of the United States*, published in London in 1832 and also in the same year in an *Atlas of the United States of North America*, published in London and Philadelphia. The atlas was made up of the maps from Hinton's *History* with condensed text. The geological map and sections and most of the other maps were not included in the several American editions of this popular work.

This map deserves particular notice, for it was the first to show anything of the geology west of the Mississippi Valley. The geology east of the Mississippi was obviously taken from Maclure's maps, and that of the region westward to the "Chippewayan Mountains" could only have been developed from Edwin James's geological results of Long's Expedition to the Rocky Mountains published in 1822–23. The plate following the map in both Hinton's book and the atlas is a copy of James's geological sections across the United States, and the legend on the map uses James's geological nomenclature. Although James did not publish a geological map, his route map has a few geological boundaries indicated for the western section, and might be considered a geological map of the western part of the United States. Unfortunately there is no indication in Hinton's work as to just who, among the "several literary gentlemen in America and England" who are mentioned as having contributed to the book, compiled the map and accompanying geological text. Both are skilfully done, evidently by someone who had some acquaintance with geology but who added little or nothing beyond information already published.

Eleven years after the appearance of this eleventh geological map of the United States saw the publication of James Hall's far better and more detailed map of the Northeastern States (1843). This was followed two years later by Lyell's beautifully executed map of the eastern half of the country. With these the pioneer era of American geological maps came to a close.

REFERENCES

BEAUJOUR, L. A. F. *Aperçu des États-Unis, au commencement du XIX^e^ siècle, depuis 1800 jusqu'au 1810 avec des tables statistiques:* 274 pp.; map, 17 tables. Paris, 1814.

CHINARD, G. *Volney et l'Amérique, d'après des documents inédits et sa correspondance avec Jefferson.* Johns Hopkins Stud. in Romance Lit. and Lang. **1**: 206 pp., portr. 1923.

CLEAVELAND, P. *An elementary treatise on mineralogy and geology, . . .:* xii, 668 pp., 5 pls., map. Boston, 1816. Second ed.: 2 vols., xii, pp. 1–480, 481–818, 5 pls., map, Boston, 1822.

EVANS, L. *An analysis of a general map of the Mid-*

dle British Colonies in America ...: iv, 32 pp. Philadelphia, 1755.

FULLER, J. *The Naval Chronicle:* 3 vols. London, 1760.

GUETTARD, J.-E. *Mémoire dans lequel on compare le Canada à la Suisse, par rapport à ses minéraux.* Mém. Acad. Roy. Sci. (Paris), Ann. 1752: 189–220, pl. 7; 323–360, pls. 8–12; Addition, 524–538. 1756. Also: duodecimo edition, t. **2**: 281–328, pl. 7; 480–538, pls. 8–12. Amsterdam, 1761.

HALL, JAMES. *Geology of New York. Part 4, comprising the survey of the Fourth Geological District:* 683 pp., map, 19 pls., 74 figs. Albany, 1843.

HINTON, J. H. *The history and topography of the United States: edited by John Howard Hinton, A.M., assisted by several literary gentlemen in America and England ...,* 2 vols. (Geology, vol. 2, p. 45–89, geological map opposite p. 45). London, 1832. See also: *An atlas of the United States of North America, corrected to the present period, ...:* 58 pp., 16 maps, 1 pl. London (third map is geological). (The atlas sold for 2 guineas plain, 3 guineas colored.)

IRELAND, H. A. *History of the development of geologic maps.* Bull. Geol. Soc. Amer. **54**: 1227–1280. 1943.

JAMES, E. P. *Account of an expedition from Pittsburgh to the Rocky Mountains performed in the years 1819 and '20 ... under ... command of Major Stephen H. Long,* 2 vols. (1823), 503 pp.; 442, xcviii pp. Atlas (1822), 2 maps, 8 pls., pl. of sects. Philadelphia.

LEIGHTON, H. *One hundred years of New York State geologic maps, 1809–1909.* Rep. Director New York State Mus. for 1908: 115–155, 1 map. 1910.

LYELL, C. *Travels in North America: with geological observations on the United States, Canada, and Nova Scotia,* 2 vols. London, 1845.

MACLURE, W. *Observations on the geology of the United States, explanatory of a geological map.* Trans. Amer. Phil. Soc. **6**: 411–428, map (43.5 × 53.5 cm). 1809.

———. *Observations sur la géologie des États-Unis, servant à expliquer une carte géologique.* Journ. Physique **69**: 204–213. 1809.

———. *Suite des observations sur la géologie des États-Unis servant à l'explication de la carte ci-jointe.* Journ. Physique **72**: 137–165, pl. 1 (map, 40 × 52.7 cm). 1811.

———. *Observations on the geology of the United States of America ...:* 127 pp., map (36.5 × 43.7 cm), plate of sections. Philadelphia, 1817.

———. *Observations on the geology of the United States of America ...* Trans. Amer. Phil. Soc. (n.s.) **1**: 1–91, map (31.5 × 42.5 cm), plate of sections. 1818.

———. *Some speculative conjectures on the probable changes that may have taken place in the geology of the continent of North-America east of the Stoney Mountains.* Amer. Journ. Sci. **6**: 98–102. 1823.

MARCOU, J., AND MARCOU, J. B. *Mapoteca geologica Americana, 1752–1881.* U. S. Geol. Surv. Bull. no. 7 (with supplement). 1884.

MARCOU, J. *Second supplement to Mapoteca geologica Americana.* Amer. Geol. **11**: 95–99, 1933.

MERRILL, G. P. *Contributions to the history of American geology.* Rep. U. S. Nat. Mus. for 1904: 189–734, 37 pls., 141 figs. 1906.

MITCHILL, S. L. *A sketch of the mineralogical history of the State of New-York.* Medical Repository (N.Y.) **1** no. 3: 293–314 (1798); no. 4: 445–452 (1798); **3**, no. 4: 325–335 (1800).

———. *A sketch of the mineralogical history of the State of New-York.* Trans. Soc. Promotion Agriculture, Arts, and Manufactures (New York), pt. 4: 124–152. 1799. (Second edition, 1801.)

———. *Additional articles of my report to the Agricultural Society on the mineralogy of New-York.* Medical Repository **5**: 212–215. 1802.

———. (*Review of Volney's Climat et Sol des États-Unis.*) Medical Repository **8**: 172–196; 410–420. 1804–05.

———. *Maclure's geological enquiries.* Medical Repository **12**: 295–296. 1809.

RAFINESQUE, C. S. (*Review of Maclure's Observations on the geology of the United States of America, 1817.*) Amer. Monthly Mag. and Crit. Rev. **3**: 41–44. 1818.

STANTON, T. W. *The evolution of the geologic map of the United States* (abstract). Journ. Washington Acad. Sci. **23**: 485. 1934.

VOLNEY, C.-F. CHASSEBOEUF, Comte de. *Tableau du climat et du sol des États Unis d'Amérique; suivi d'eclaircissemens sur la Floride, sur la colonie française au Scioto, sur quelques colonies canadiennes et sur les sauvages ...,* 2 vols., xvi, 300 pp.; pp. 301–534, ii, 4 pls., 2 maps, 1 section. Paris, 1803 (An. XII).

WHITE, G. W. *Lewis Evans' contributions to early American geology, 1743–1755.* Trans. Illinois Acad. Sci. **44**: 152–158. 1951.

———. *Lewis Evans (1700–1756): a scientist in colonial America.* Nature **177**: 1055–1056. 1956.

Emergence of Geology as a Public Function, 1800–1879

By WILLIAM BACK, *U. S. Geological Survey*

The congressional act of March 3, 1879, that created the U. S. Geological Survey marked the acceptance of geology as a science having permanent value for and deserving permanent support from the American people. Even earlier, organization of the four western surveys which were consolidated by the act of March 3, 1879, demonstrated a change in the public attitude toward their national government. This change prompted Henry Adams (1918, p. 312) to refer to the congressional authorization for the exploration of the fortieth parallel as "almost its first modern act of legislation." In this paper I attempt to indicate some of the political and administrative attitudes that accounted for a delay of nearly 100 years after the Constitutional Convention before geology achieved this recognition. Part of the answer lies, of course, in the slowness of development of geology itself, because the growth and public support of a science progress concurrently. The science can not be actively supported until it develops, nor can it develop until it is actively supported.

Another reason for the delay was that during the Jeffersonian period, 1801–29, the climate of the time was not favorable to the extension of Federal Government functions and expenditures. The policy was stated by Jefferson in his first annual message: "Agriculture, manufactures, commerce, and navigation, the four pillars of our prosperity, are then most thriving when left most free to individual enterprise" (White, 1951, p. 23). It was a period of consolidation and growth but not of expansion. Jefferson's and Adam's interest in the appreciation of science was generally not shared by others who, through their political positions, could have facilitated the promotion of scientific studies.

Nor was the philosophical attitude as to the proper functions of the Federal Government significantly changed during the Jacksonian period of 1829–61. President Van Buren stated the underlying Democratic philosophy clearly and unequivocally in his message to Congress in 1837. "All communities," he declared, "are apt to look to government for too much . . . But this ought not to be. The framers of our excellent Constitution and the people who approved it with calm and sagacious deliberation acted at the time on a sounder principle. They wisely judged that the less government interferes with private pursuits the better for the general prosperity . . . its real duty . . . is . . . to leave every citizen and every interest to reap under its benign protection the rewards of virtue, industry, and prudence." Governmental policy followed this philosophy consistently (White, 1954, p. 6).

While the National Government was used by its citizens hardly more in 1860 than it was in 1800, the States and their subdivisions were actively pushing into new fields, unhampered by the constitutional doubts of statesmen on the national scene, although restrained in some measure by the dominant philosophy of laissez faire (White, 1954, Preface).

The movement for public education, inspired and led by Horace Mann, reflected the desire for more informed public opinion. A convention of organized workingmen meeting in Boston in 1833 resolved that no person would receive the votes of its members "but such as are known to be openly and decidedly favorable to a system of general education, by means of manual labor schools, supported at public expense, and open alike to the children of the poor as well as to the rich . . . " This resolution was symptomatic of the future, as Americans came to realize that government could make positive, constructive contributions to the needs of the people without necessarily creating either a threat to liberty or a drain on the Nation's resources (White, 1954, p. 10). Coming as it did in 1833, this resolu-

tion may be a manifestation of the same intellectual forces, the same general awakening of the desire for knowledge, that prompted the organization of the State geological surveys—17 of them during the period 1830–40 alone (Fig. 1).

As to more positive contributions by the Federal Government, however, it is doubtful that much could have been accomplished even if the prevailing attitude had been more favorable. The years of the Jacksonians, from 1829 to 1861, were years of almost uninterrupted excitement, tension, crisis, and apprehension. Nullification in South Carolina, the resolution censuring Jackson and its final erasure from the Senate Journal, the panic of 1837, the controversy with Great Britain over Oregon, the war with Mexico, the problem of slavery in the newly acquired territories leading to the Compromise of 1850, the moral and administrative crises precipitated by the Fugitive Slave Act, the panic of 1857, John Brown's raid—all these events gave neither the politicians nor the people any peace (White, 1954, p. 18). Congress and the administrators had little time for expanding the function of science in government.

Another reason, as we have said, is that geology was a young science which, at least so far as the Federal Government was concerned, had not yet proved its practical value and was considered theoretical and academic. The general intellectual environment in the United States was not conducive to active participation in theoretical sciences. We have the clearest description of the attitude of the times in Tocqueville's perceptive writings where he states (1900, vol. 2, p. 43), "In America the purely practical part of science is admirably understood, and careful attention is paid to the theoretical portion which is immediately requisite to application. On this head the Americans always display a clear, free, original, and inventive power of mind. But hardly anyone in the United States devotes himself to the essentially theoretical and abstract portion of human knowledge."

Thus we see that the political and administrative philosophy was not compatible with support of geology on the Federal level, and that whatever was to be done with public support necessarily became the responsibility of the State governments. The defeat of John Quincy Adams in 1828 marked the climax of his effort to use national power and resources for what he con-

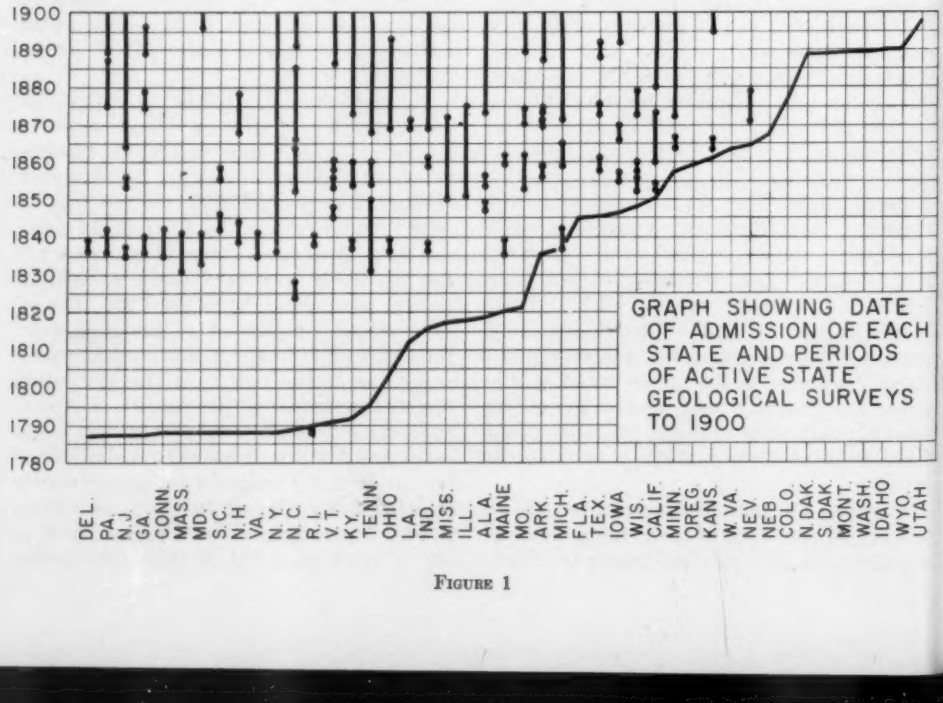


FIGURE 1

ceived to be national purposes. I think this may have brought about the general realization that the States would have to assume greater responsibilities, and it is particularly significant to geology in that it happened immediately before the first State surveys were formed in the 1830's.

This is not to imply that the Federal Government was completely inactive in geologic exploration but only that the States were taking the lead and dominating that part of geology supported directly by public funds. As we know, we had the expeditions of Schoolcraft, Lewis and Clark, Pike, Long, Wilkes, and Frémont; the Pacific Railway Survey; and others during the period 1803 to 1860. Geologic knowledge was gained from all these expeditions, but geology was not their primary purpose. The authorizations of the surveys of Featherstonhaugh in 1834–35 and of David Dale Owen in 1839 were the first Federal attempts to support geologic investigations.

It is interesting to speculate on the possible causes of the flourishing of the State surveys in the 1830's (Fig. 1). Of the 13 original States only two did not start a survey during the decade 1830–40; one of these, North Carolina, had had a token survey a few years earlier, and the remaining State, South Carolina, began its survey only two years after the end of this decade. (It is also of interest to note that the Geological Survey of Great Britain was organized in 1835.) Were these States only imitating Massachusetts and North Carolina, the early birds, or had geology truly become a science, as Smallwood suggests? He states (1941, p. 441), "Geology, the third large department of natural history, stands out in rather marked contrast to botany and zoology. During the period designated as 'the passing of the naturalist' (1830–40), in which the naturalist, after acquiring great influence, rather rapidly declined, geology became very prominent in the making of State surveys. The naturalists' emphasis was being replaced by the adoption of scientific criteria that any geologist could apply."

I think we cannot completely disregard the role of chance in the nearly simultaneous beginning of the surveys. That is to say, there was enough general activity in geology to permit this sudden development. The establishment of the American Journal of Science in 1818 and of the American Geological Society in 1819, the publication of Eaton's Index to the Geology of the Northern States in 1818, and the organization of the Geological Society of Pennsylvania in 1832 were significant items in bringing geology to the forefront.

Nor do I think we can overlook the role of individual personalities as contributing factors. We see the rise of strong leaders such as Edward Hitchcock, who was responsible for the conception and establishment of the first State geological survey, that of Massachusetts; the Rogers brothers, responsible for three of the early surveys; W. W. Mather, who made the Ohio and Kentucky surveys; C. T. Jackson, also responsible for three State surveys; David Dale Owen, who started the Indiana survey; and Amos Eaton, whose lectures to the New York State Legislature no doubt were the beginning of that State's survey.

Regardless of which of the several possibilities was dominant, we see from Fig. 1 that the early State surveys were short-lived, not only those that began during the early period but even those that began later. The short life of these surveys no doubt could be explained by many reasons, such as adverse economic conditions, internal political changes, or shortage of competent personnel. But I think none of these come as close to the truth as that suggested by the Federal Survey's Director Mendenhall in describing the tremendous task confronting the men who undertook the first survey of Pennsylvania: "An adequate study of 45,000 square miles of extremely varied and complex geology and the revelation of the wide variety of mineral resources that it contains, would tax the capacity of a large modern staff, trained according to modern standards, and equipped with complete modern maps. It couldn't be done promptly, of course, a century ago. Base maps were lacking; trained geologists were very few. Principles had to be established and methods devised as the work proceeded. The magnitude of the task was tremendous and dawned only slowly on the workers. Results

came in slowly so that the State lost patience and in six years appropriations ceased" (Mendenhall, 1936, p. 17).

It was no doubt this same impatience that caused nearly continuous difficulty in establishing permanent State surveys. Tocqueville apparently recognized this characteristic of our society and in effect predicted the difficulty that activities such as State geological surveys would face in gaining general acceptance. He comments, "The man of action is frequently obliged to content himself with the best he can get, because he would never accomplish his purpose if he chose to carry every detail to perfection . . . The world is not led by long or learned demonstrations" (Tocqueville, vol. 2, p. 44).

Therefore, when geology did not yield results immediately capable of application to current wishes, the "men of action" saw no need for further support and the surveys ceased. As the reports were later published and use could be made of the geologic knowledge from the surveys, most of the States again organized surveys, the later ones generally being longer lived than the earlier ones. The State surveys continued to dominate the public activity in geology until the Civil War.

Although three States started surveys during the Civil War, this generally was a period of disruption in geology, lost records, and diversion of personnel. After the war we see a great increase in geologic interest and activity by the Federal Government. Merrill states, "The period of the Civil War had brought to light a considerable number of men . . . of great physical and moral courage. It was but natural, therefore, particularly when the necessity for military routes in the west and public land questions were taken into consideration, that such should turn their attention toward western exploration. Further, the surveys made in 1850's, in connection with routes for the Pacific railroads, and the work done by Evans, Hayden, and Meek in the Bad Lands of the Missouri had whetted the desires of numerous investigators. Willing workers were abundant and Congress not difficult to persuade into granting the necessary funds" (Merrill, 1924, p. 500).

This change in the attitude of Congress marks a significant step in the emergence of geology as a public function. Only a few years before, in 1852, Congress specified that no new geological surveys be undertaken unless authorized by law. I think this change in attitude may be attributed at least in part to a gradual shift in the point of initiation of new functions in the Government. In the early periods we see the President taking a very active role in developing new functions. For example, Thomas Jefferson wrote detailed instructions for Lewis and Clark to follow on their expedition. A few decades later Congress is perplexed with the problem of doing something constructive with Smithson's estate. The act creating the Smithsonian Institution was one of the earliest modern acts of Congress to take a positive and constructive attitude toward a new function. Still later, as the tasks and responsibilities of the Government increased, I believe we can see the initiation of new functions taking place in the newly organized and expanding departments. Here the debates are not among the members of Congress as much as between the Congress and the administrators. Therefore, as the potential leaders of western surveys sought Congressional appropriations, the logic of their arguments added force to governmental processes and facilitated the beginning of new functions. As these western surveys gained in strength and popularity it was only a step in the direction of more economical operation to create the U. S. Geological Survey by combining their purposes and personnel.

In summary, I have attempted to outline the political and administrative philosophy from about 1800 to 1879 as it bears on the emergence of geology as a public function. I have ignored almost entirely the force of geology itself. Nor have I considered the very significant contributions made by the land-grant colleges and other publicly supported educational institutions. Other items I have ignored, in deference to other papers in this symposium, are, for example, the role of the Smithsonian Institution, the activities of the AAAS, the effect of Darwinian concepts, the popularization of geology, and the development and use of topographic

maps. Indeed, every contribution to the advancement of geology must be considered a part of the story of the emergence of geology as a public function.

ACKNOWLEDGMENTS

This paper was developed from several term reports prepared for courses in public administration at Harvard University. The stimulation and guidance of Prof. John M. Gaus in the study of the historic connection of science and government and the helpful suggestions of C. L. McGuinness of the United States Geological Survey are gratefully acknowledged.

REFERENCES

ADAMS, HENRY. *The education of Henry Adams:* 517 pp. Boston, Houghton Mifflin Co., 1918.

MENDENHALL, W. C. *Establishment of Pennsylvania survey—an outstanding event in development of science in U. S.* Pennsylvania Dept. Internal Affairs Monthly Bull. **2**(1): 17–18. 1936.

MERRILL, G. P. *The first one hundred years of American geology.* Yale University Press. 1924.

SMALLWOOD, W. M. *Natural history and the American mind:* 445 pp. New York, Columbia University Press, 1941.

TOCQUEVILLE, ALEXIS DE. *Democracy in America* **1**: 442 pp.; **2**: 399 pp. New York, Colonial Press, 1900.

WHITE, L. D. *The Jeffersonians:* 572 pp. New York, Macmillan Co., 1951.

———. *The Jacksonians:* 593 pp. New York, Macmillan Co., 1954.

The United States Geological Survey and the Advancement of Geology in the Public Service

By THOMAS B. NOLAN, *Director, U. S. Geological Survey*

The Geological Survey will be 80 years old on March 3, 1959. It came into being that date in 1879, when President Hayes signed an appropriation bill that contained an item giving the Director of the Geological Survey the responsibility of administering a new organization, which was directed to classify the public lands and to examine the "geological structure, mineral resources, and products of the national domain."

This rather oblique method of creating the new organization was perhaps an appropriate conclusion to the struggle for support —especially financial support—by four predecessor exploratory surveys which were by this action combined into one. The union was accomplished largely through the acceptance by the Congress of the major recommendations of a committee set up by the National Academy of Sciences at its request. The infant bureau thus, at its inception, enjoyed the sponsorship of the leading scientific group of the country. It has been fortunate since that time to have had continued assistance in the selection of its directors, through recommendations by this same Academy.

The four predecessor surveys were each established in the years following the Civil War. They were to aid in developing the West, through the acquisition of additional knowledge of its geography and of its resources. Their objectives, and those of the young Geological Survey, were primarily the practical ones of exploring the geographic frontier, in part to learn about new or better routes by which it might be traversed; in part to discover and appraise the natural wealth of the new territory. Emphasis was, of course, laid upon the mineral wealth, but the soils, the water and forest resources, and even the scenic features had to come under scrutiny if the objectives were to be attained.

To achieve success in this sort of an exploration of a physical frontier, it is now apparent that it was necessary to develop both new concepts and new techniques. It was fortunate that the members of the early surveys and of the new Geological Survey

had the capacity to do this; they were able, in a sense, to use the results of their exploration of intellectual frontiers in the attainment of their practical objective of delimiting the geographic one.

The record of the Survey in subsequent years seems to me to illustrate a continuing ability to utilize the products of intellectual curiosity in the solution of the practical problems that arise in our economy. The industrialization of the country, following the development of the West; participation in two World Wars; and currently the need to resolve difficult and perplexing problems in water and mineral supply have each been accompanied by reorientations in the research programs of the Survey, with concomitant applications of research results to the problems themselves.

I believe this ability to recognize, or anticipate, national needs and to use research results in their solution has been the most significant contribution by the Survey to the "advancement of geology in the public service."

With this preface, I should like to review very briefly the history and activities of the Geological Survey since its founding. Clarence King was the first director; he served for only two years, but in that brief period a staff of outstanding scientists was gathered, several geologic studies were begun, a chemical laboratory was set up in Denver, topographic surveys were begun in Nevada, the Survey's first geophysical work was started as part of the study of the Comstock Lode, and, in cooperation with the Census Bureau, the collection of statistics on yearly mineral production in the region west of the 100th meridian was begun. Thus, from the very beginning both practical and theoretical investigations, or applied science and basic research, were part of the Survey program.

Establishment of the Survey did not put an end to the controversy over the function of a Government bureau engaged in scientific activities. John Wesley Powell, who had been instrumental in the founding of the Survey and who had succeeded King as director, had as his goal the establishment of the Survey as a great scientific and technical bureau with emphasis on research in all its functions. Shortly after he assumed office, paleontological laboratories were established, a physical laboratory was set up for research on the effect of temperature, pressure, and related phenomena on rocks, and studies of metamorphism and the paragenesis of minerals were begun. In 1882 congressional authorization was given "to prepare a geologic map of the United States," thus leaving no doubt as to the national extent of the Survey's work; and to procure statistics in relation to mines and mining, thus placing on a permanent basis work that had been undertaken in cooperation with the Tenth Census. And the Survey was making a topographic map of the United States because, as Powell pointed out, sound geologic research is based on geography.

By 1884 this vigorous prosecution of work and rapid expansion of the Survey had provoked considerable discussion in both public and private circles, and a Congressional committee undertook an investigation of the several scientific bureaus to attain greater efficiency and economy in their administration. In his appearances before this committee Powell established a philosophy which has become the guiding principle of the Survey in later years that a Government research agency should promote the welfare of the people by investigations in those fields most vitally affecting the great industries in which people engage, should have the broadest possible territorial base, and its work should not be undertaken in those fields where private enterprise may be relied on for good and exhaustive work. The majority report was favorable, and Congress, by specific appropriation, endorsed the chemical, physical, and paleontologic work of the Survey.

In addition to its regular scientific work, three major problems in conservation occupied the Survey during the first third of its history. In 1888 Congress authorized the Survey to undertake a study of the arid regions where irrigation was necessary to agriculture. In 1894 and in subsequent years the Survey received appropriations for gaging streams and determining the water supply of the United States. When the Reclamation Act was passed in 1902, its administration was assigned to the Survey

until the work changed from planning to construction. In 1907 the Reclamation Service became an independent bureau and the chief of the Geological Survey's Hydrographic Branch became its first director.

In the course of its geologic and topographic surveys, the Survey had gathered data related to forests, and in 1891 Congress authorized creation of forest reserves on the public lands. A comprehensive study of forest reserves was begun in 1897, and land classification maps were prepared to form the basis for regulations governing the reserves. In 1905 the Forest Service was established in the Department of Agriculture and took over the further examination and classification of forest reserves as well as the administration of regulations.

Mining geology and mining technology had been an important part of the Survey's work from the start. Beginning in 1883, an annual volume of statistics on the mineral resources had been prepared. Public interest in a separate division of mines to serve the needs of the mining industry developed fairly early. But it was some years later (1908) when the Survey was authorized to undertake an investigation of mine safety. These activities were somewhat outside the normal work of the Survey and were later transferred to the Bureau of Mines, which was established by congressional act of May 16, 1910, along with the Technologic Branch of the Survey, whose chief became the first director of the Bureau.

Meanwhile the regular geologic work of the Survey had progressed. Investigations had been undertaken in Alaska, Hawaii, Puerto Rico, and Cuba. Nearly a third of the country had been mapped topographically, at least in reconnaissance, geologic folios had been published, and some 400 reports had been published on such topics as Lake Bonneville, the Paleozoic fishes of North America, the glacial gravels of Maine, borax deposits in Death Valley, and tin in Alaska, on the chemical composition of igneous rocks, the form of sea level, earthquakes in California, and the compressibility of liquids. Its investigation in the Leadville district had shown the practical importance of geologic studies in mining, those in the Lake Superior region had an effect on discovery and development, and studies in the Appalachian coal field were pointing the way toward a scientific basis for development of natural fuel resources.

The middle third of the Survey's history is nearly coincident with the directorship of George Otis Smith. It was Smith's idea that a scientific bureau should collect and arrange facts upon which the Nation could base its plans for future development and should make its science useful to the public. Basic research was encouraged but there was increased emphasis on and a widening of the Survey's usefulness in applied science.

During his first decade in office the general public was in closer touch with the Survey and made more use of its scientific results than ever before. In one year it was reported that approximately 50,000 letters of inquiry were handled in the different scientific branches. In a special publication, Bulletin 599, entitled *Our mineral reserves*, the country's ability to meet emergency demand was summarized and the Survey offered to serve as an agent in bringing consumer and producer into touch with each other. In recognition of its responsibility to make its work intelligible to the layman, nontechnical descriptions of the physical features and their origin were printed on the backs of several topographic maps, and guides covering points of scenic or unusual geologic interest in some of the national parks and along several transcontinental routes were prepared.

Efforts to assist in discovering and developing new oil reserves were intensified, field studies seeking a better understanding of the principles and conditions governing the origin, movement, and segregation of oil and gas were begun, and field investigations of the oil shale reserves were also under way. After Germany gained a monopoly of the potash supply, Congress directed the Survey to explore for domestic deposits, and intensive and ultimately successful exploration was carried out in the western States. Another notable contribution to geology in its broadest sense was the study by G. K. Gilbert of hydraulic mining debris in the Sierra Nevada which involved mining, agriculture, and navigation problems as well as geology.

With the advent of the first World War, scientific knowledge and methods were applied to the technology of weapons, and the need for basic raw materials brought to the Survey an important role in the war effort. Scientific data already available in the Survey formed the basis of special investigations of certain mineral deposits and an increased exploration for new deposits. The strategic minerals concept was first developed at this time, and a beginning was made in military geology as information on potential mineral and water resources of other countries was gathered.

The war had shown the need for increased development of power sources. During the war Survey hydraulic engineers had made a countrywide survey of the power situation to determine where water power could be substituted for steam-generated power. After the war a survey of sources of energy in the Washington-Boston area, the so-called Superpower Survey, was undertaken by congressional authorization. The Federal Coal Commission was set up in 1922 and took the director away from the Survey for a year; in 1924 he was appointed to a Federal Oil Conservation Board and to a naval oil supply commission; in 1925 he was delegate to the World Power Conference, and in 1930 the newly established Federal Power Commission took him permanently from the Survey.

The last third of the Survey's history has been one of relatively rapid and great changes and an even more intimate involvement of the Survey with the national development. During the depression years of the early 30's, appropriations were so reduced that many were forced to leave the Survey and many projects were suspended. Through allocation of funds from the Public Works Administration and other agencies some of the Survey programs, notably topographic mapping and investigations of mineral resources in the Southeastern States, were continued, and in 1936 increased appropriations made possible more normal operations.

In 1939, with the threat of approaching war, Congress authorized the beginning of strategic mineral investigations, and when the war started a high proportion of Survey men were shifted to this work. A military geology group was formed immediately after the United States entered the war and grew rapidly as its work became more and more useful to the armed services. Appraisals of characteristics of enemy terrain were made for use in strategic planning, and Survey scientists went into the war theaters to aid in planning tactical operations. An investigation of fissionable raw materials begun at the request of the Manhattan Engineer District was expanded after the war on behalf of the Atomic Energy Commission to a major program that involved both exploration and basic research in the geology of fissionable materials.

In the post-war years, also, engineering geologic investigations have been undertaken in support of the program of the Department of the Interior for river-basin development, and geologic mapping of fast-growing industrial areas has provided data needed in many types of engineering construction in expanding urban areas. Research has also been undertaken on geologic processes, such as the development of landslides, that affect the safety of engineering structures.

In the Survey's traditional fields of geologic mapping and appraisal of the mineral resources of the Nation there has been a constant awareness of the need for continual development of new exploratory tools and improvement of techniques as the expanding economy calls for ever-increasing amounts of raw materials and advancing technology creates demands for new materials. Geochemical prospecting methods have been developed to aid in the discovery of mineral deposits. New, rapid, sensitive, and inexpensive analytical methods suitable for use in the field have been developed, and geobotanical and hydrogeochemical techniques have been investigated. Geophysics has taken to the air, and magnetic and radioactivity surveys have been made of many thousands of square miles. Geologic mapping techniques are being improved notably by the development of photogeology to obtain greater coverage more rapidly and at less cost.

More than ever before we need to develop an understanding of the processes by which mineral deposits are formed in order to develop the scientific techniques required to guide the search for new sources. As part of a long-range minerals program, more and more data are being sought on the physical properties of rocks, on the nature of the ore-forming fluids, on the physical, chemical, and biochemical changes that take place in weathering.

Geologic facts and techniques are being used in an ever-increasing variety of problems. Airborne radioactivity surveys developed to aid in exploration for new sources of uranium are being adapted to monitoring the effects of nuclear explosions on atmospheric radioactivity, and both geophysical and geochemical methods are being used in a study of the relation of environmental factors to the development of cancer, and measurements of the temperature in frozen ground turn out to be significant in the design of buildings, roads, and other construction and the location of water supplies in our forty-ninth State.

This recital of activities and policies since 1879 is in part abridged from the excellent historical summary prepared by John and Mary Rabbitt on the occasion of the seventy-fifth anniversary of the Geological Survey; it was published in Science in 1954. The chronological recital alone, I think, records the very considerable contributions that the organization has made to the "advancement of geology in the public service." I should like, though, to further summarize by pointing out four broad categories in which these activities have been especially productive.

One might be categorized as the development or refinement of new fields or new principles. I believe that it is fair to say, for example, that mining geology as it is practiced today is very largely the product of Survey work. This began with Clarence King who, in addition to his own activities, sponsored the work of Becker in the Comstock and S. F. Emmons in Leadville, continued through the widespread activities and generalizations of Lindgren and the timely analysis of the newly developed porphyry copper deposits by Spencer and Ransome, and is operative to the present day through the field development of airborne and geochemical exploration methods, and the laboratory researches of the Geochemistry and Petrology Branch. An even stronger case might be made for the new field of groundwater hydrology with the early work of Mendenhall in southern California, the long period of development under Meinzer, and the more recent investigations by Sayre, Theis, and others.

Contributions to geologic thinking and to the development of principles are basically made by individuals, rather than organizations, but the latter can provide an environment in which individual contributions may flower. I believe this has been true in the Geological Survey; certainly our basic concepts in sedimentation and stream dynamics have been continuously influenced by the work of Gilbert, Rubey, and, most recently, by Leopold. Similarly, glacial geology has been influenced by Survey authors from T. C. Chamberlain through Alden and Matthes; structure, from Dutton to Gilluly, petrology from Hague through Cross to E. S. Larsen, Jr. The list could be greatly expanded.

Less glamorous, perhaps, but certainly of inestimable value to the profession have been the numerous new or improved tools or techniques that have resulted from the Survey's work. The *Bibliographies of North American geology, Lexicon of geologic names,* and *Data of geochemistry* are examples of published contributions that are invaluable to the practicing geologist, while a whole series of proposals or developments from the standardization of cartographic methods for geologic maps to the devising of the numerous instruments and methods of photogeology have made it possible for geologists to do their field work and write their reports more accurately and more effectively.

The third category has been alluded to in previous paragraphs. It might be called the recognition, and sponsoring, of new and desirable areas of endeavor in fields related to geology and earth science. The establishment of such Federal agencies as the Forest

Service, Bureau of Reclamation, Bureau of Mines, and the Grazing Service (now a part of the Bureau of Land Management) and the non-Federal Geophysical Laboratory, resulted directly from activities initiated in the Geological Survey. I suppose some may feel that the creation of additional Federal agencies is a dubious contribution, but I believe most thoughtful observers will concur in the belief that the part played by the Survey in the creation of professional agencies in the resource management field with the high standards that characterized the parent agency has been a significant contribution to the Nation's wellbeing.

Finally, I feel that the Survey has played a large and beneficial role in education in this country that is in addition to the contributions to geologic thinking that I have mentioned. In part this has been the result of its personnel policies and in part of its extensive publication program. In regard to the first, the bureau has from the beginning encouraged an interchange of personnel between its staff and that of university faculties in geology as well as in the summer employment, as field assistants, of advanced students in geology. This policy has led to the widespread use of the so-called "w. a.e." appointments; these are operative only when the individual, usually a university teacher, is actually employed—commonly during the summer field seasons. Among the earliest appointments recorded in the Survey archives are those of T. C. Chamberlain (who received the magnificent sum of "$10 per diem, paid only when actually employed"), J. P. Iddings, O. C. Marsh, and a number of others. Utilization of men such as these not only benefited the Survey through the individual skills thus made available but also inevitably contributed to the universities and to geologic education, by making available promptly as instructional material the results of field and laboratory work of not only the w. a. e. teachers but of the Survey staff with whom they were in contact. This interchange of personnel and the widespread utilization of "w. a. e." appointments is still a major element in Survey policy.

Possibly even greater assistance to geologic education has been provided by the several series of publications which record the results of the Survey's work. I suspect that directly, through the use of such classics as Gilbert's Lake Bonneville monograph, and indirectly, through the contributions of Survey material in textbooks and lectures, almost all of us in the geologic profession are indebted, more than we recognize, to this long series of reports on the Survey's field and laboratory work.

It is apparent that I believe the Geological Survey has contributed significantly to both the advancement of geology and the public service. To me the real and lasting contribution made by the Survey, and by the other Federal scientific agencies, is the part they have played in securing general recognition, throughout the country, not only that scientific and professional work of the highest quality is possible in the Federal Government, but that it has been one of the essential contributions to the development of this Nation to the international power that it is today.

I observed earlier in this paper that a transition from an exploration of a geographic frontier to an intellectual one characterized the early work of the Geological Survey. In recent months, some of our more inquisitive younger members have proposed various studies of the geography of the individual components of "outer space." Perhaps we are about to see the beginning of a new cycle in the history of the Geological Survey in the public service.

The Role of the Smithsonian Institution in Early American Geology

By PAUL H. OEHSER, *Smithsonian Institution*

The concern of the Smithsonian Institution with the science of geology began very early in its history. It was, indeed, inherent in its very foundation; for James Smithson, the Englishman who left his fortune to the United States of America "to found at Washington an Institution for the increase and diffusion of knowledge among men"—this disappointed, lonely man who had never been to America but somehow caught the vision of the potential of such an establishment on American soil—was himself something of a geologist. While still a young Oxford student he geologized through the British Isles and thereafter assembled a large collection of gems and minerals and made noteworthy studies of them. Today, on entering the beautiful new Hall of Gems and Minerals at the Smithsonian, one can read this label accompanying a colorful specimen of smithsonite (zinc carbonate):

"This mineral was named [by Beudant] in honor of its discoverer, James Smithson, distinguished English chemist and mineralogist and founder of the Smithsonian Institution. Despite the primitive chemical apparatus and crude reagents which Smithson had to use, he was able to achieve analytical results of the most creditable character and to enlarge our knowledge of many mineral species. Before his time zinc carbonate and zinc silicate were confused as a single mineral species under the name *calamine*, but his researchers distinguished the two minerals which are now known as smithsonite and hemimorphite."

When the Smithsonian Institution was finally established by act of Congress in 1846, on the basis of a broad interpretation of the provisions of Smithson's will, geology and mineralogy were included among the Institution's concerns. In fact, James Smithson's personal collection of minerals came as a nucleus of the great national collections in this field that have accumulated through the years.

The first Secretary of the Smithsonian was Prof. Joseph Henry. He was a "natural philosopher" and made his principal contributions to science in the field of electricity; but he began as a geologist in his native New York State in the days of Amos Eaton under whose influence he came. When, in 1820, Eaton was commissioned to conduct an agricultural and geological survey of Albany County, N. Y., he chose the 23-year-old Joseph Henry as an assistant. Six years later, Henry received an appointment as engineer on a survey for an east-west road through New York State, an assignment in which he notably acquitted himself. It is said that "his labors in this work were exceedingly arduous and responsible. They extended far into the winter, and the operations were carried on in some instances amid deep snows in primeval forests." He was offered the job of directing the construction of a canal in Ohio, but the vacant chair of mathematics at the Albany Academy beckoned, and this budding geologist-engineer abandoned canal-building for the classroom. His third published scientific paper, *Topographical sketch of the State of New York; designed chiefly to show the general elevations and depressions of its surface*, which appeared in the Transactions of the Albany Institute in 1829, capped this phase of this career. Henry too was a lifelong friend of James Hall, the eminent State geologist of New York, from whom he must have assimilated considerable geologic nourishment.

I dwell on Henry here because a few years later it was put into his power to organize and shape the destiny of the Smithsonian Institution, and there can be little doubt that his knowledge of geology and its methods and his understanding of the importance of the science of geology to the growth of the country had its impact on the course the Institution was to take. This knowledge and understanding were reflected

particularly in two directions—exploration and publication.

Henry had as his Assistant Secretary a man as thoroughly trained in the natural sciences, particularly biology, as he himself was in the physical sciences—Spencer Fullerton Baird. Before Baird came to Washington, and up to the time the Smithsonian was founded, there had been at least half a dozen principal Western exploring expeditions, beginning with Lewis and Clark in 1804 and ending with Frémont's explorations of Oregon and California. But these were only the beginning. Soon the Bad Lands were being explored by Dr. John Evans and Thaddeus A. Culbertson. In 1849–50 Capt. Howard Stansbury led an exploring and surveying expedition to Great Salt Lake. Capt. Lorenzo Sitgreaves (1852) was exploring the Zuni and Colorado River region. The Mexican boundary survey was in progress (1854–56) under Maj. W. H. Emory. Several parties were in the field surveying for a railroad route to the Pacific. There were expeditions, also, to Chile, the La Plata region, the Amazon Valley, Greenland, and Bering Sea.

The Smithsonian's part in these efforts was considerable. In his 1854 annual report Baird described 26 important explorations undertaken during the preceding two years, including six Pacific Railroad surveys. "With scarcely an exception," he wrote, "every expedition of any magnitude has received more or less aid from the Smithsonian Institution. This has consisted in the supply of instructions for making observations in meteorology and natural history, and of information as to particular desiderata; in the preparation, in part, of the meteorological, magnetical, and natural history outfit, including the selection and purchase of the necessary apparatus and instruments; in the nomination and training of persons to fill important positions in the scientific corps; in the reception of the collections made, and their reference to individuals competent to report upon them; and in employing skillful and trained artists to make accurate delineations of the new and unfigured species. Much of the apparatus supplied to the different parties was invented or adapted by the Institution for this special purpose, and used for the first time, with results surpassing the most sanguine expectations."

All this represented the type of aid the Smithsonian rendered throughout the exciting decades of western exploration and expansion. It paid off in many ways, and all the natural sciences, including geology, benefited. The Nation benefited. Two spectacular instances are enough to mention.

On June 16, 1874, Maj. John Wesley Powell laid on the desk of Secretary Joseph Henry the manuscript of his *Exploration of the Colorado River of the West and its tributaries*, culminating Powell's explorations up to that time. The Smithsonian among others had aided the Powell expeditions in various ways, and it was the Smithsonian that sponsored the publication of the *Exploration*. With remarkable speed, it came off the press the following year. Its importance to American geology needs no recounting before this audience.

Another Smithsonian-nurtured venture of far-reaching significance was the Kennicott Expedition that in 1864 set out to explore Russian America for the Western Union Telegraph Co., which undertook to run a telegraph line to Europe by way of Alaska and Siberia after the failure of the Atlantic cable. Directing the scientific corps was the young Robert Kennicott, of the Chicago Academy of Sciences, who died of a heart attack near Nulato in May 1866. A geologist, William Healey Dall, was then put in charge. Soon afterward, Cyrus Field's Atlantic cable was assured and the Western Union dropped the whole project of an overland telegraph line, and the exploring party was disbanded. In their few months in the Far North, however, they had done remarkable work, penetrating territory never before seen or traversed by white men and gathering a wealth of natural-history data. Two of the party—Henry M. Bannister and Ferdinand Bischoff—had returned to Washington in 1867, about the time when the United States Congress was considering the purchase of Alaska from Russia. Their presence was most opportune, for they were probably the only persons in the Capital with firsthand knowledge of Russian America. Bannister, Bischoff, and Baird were

called to testify before the Senate Committee on Foreign Relations. Their story of Alaska's wealth of furs, fish, and timber, gold and copper, its unbelievable mountains and glaciers and forests, must have been a thrilling one to hear. Bannister himself later remarked: "The annexation was ridiculed at the time, but we could testify that the country was worth the price asked. Time has sufficiently proved that we were right and I can safely say that we did not overstate anything... The project of the Western Union Telegraph Company... was a failure but its greatest result was the annexation of Alaska." Almost immediately another expedition was organized by the Treasury Department to obtain additional information concerning the new Territory of Alaska, and at the request of the Secretary of the Treasury the Smithsonian furnished instructions "for research into the physical and natural history of the country." Among these instructions the following is of special interest: "Full collections should be made of the rocks and minerals of the country at the different stopping points, as well as of any fossil remains that may be found to occur. Notes should accompany these specimens showing their relationship to each other and the country itself, and illustrated by diagrams indicating the number, inclination, and relative thickness of any strata that may be observed."

There was another aspect to the Smithsonian's role of catalyst whose importance should not be minimized. It was the atmosphere it provided young scientists in Washington for study and research. In those early days the Smithsonian's funds had to be spread thin. It could not build up a large staff of geologists, biologists, physicists, anthropologists. But it could provide some of them with facilities and even living quarters. The be-towered, owl-haunted Smithsonian Building, designed by the church-building architect James Renwick, was a mecca for them. Joseph Henry and his family occupied the east "apartments" of the building. Encouraged by both Henry and Baird, many a young hopeful was allowed to occupy some unused upper room in one of the towers. One group called itself the Megatherium Club, taking its name from the field of vertebrate paleontology. The geologist Fielding Bradford Meek lived in a north-tower room from the time he went to Washington in 1858 until his death in 1876, and within the Smithsonian walls were carried on his patient and conscientious labors "by which the paleontology of the United States was so greatly advanced." The visiting Louis Agassiz spent many a night in the building as a guest of the Henrys, and there still is circulated the probably not apocryphal story of how, one night, some of the resident "boys" loosened the slats of Agassiz's bed. It is not recorded just what effect this downfall had on the future career of the famous glaciologist.[1]

Two other geologists who were the beneficiaries of Smithsonian hospitality were William Healey Dall and Lester F. Ward. Neither, so far as I know, ever lived in the building or was ever on the payroll of the Smithsonian; but Dall, explorer, paleontologist, conchologist, spent a lifetime in the National Museum's division of mollusks; while Ward, the paleobotanist who finally became the patron saint of sociology, was similarly given the keys to the Institution and did some of his finest work under its aegis. A little later, Charles Doolittle Walcott became similarly attached to the Smithsonian, where he helped to build up its invertebrate collections, particularly the Cambrian. All this provided the kind of encouragement that scientific research always needs. Throughout the latter half of the nineteenth century the Smithsonian was perhaps its most generous dispenser; and certainly, as Prof. William North Rice long ago stated, until the time the U. S. Geological Survey was organized in 1879, the Smithsonian Institution was the headquarters of the geologists in the service of the Government. In geology, as in other fields, the Smithsonian created a salubrious climate for scientific work.

In 1846 when the Smithsonian was founded, there were few outlets for the publication of sizable scientific manuscripts.

[1] Dr. T. S. Palmer, biologist and necrologist who pervaded Washington scientific circles for many years until his death in 1955, tried to find out just which room in the Smithsonian Building "the bed fell with Agassiz." If he ever discovered this bit of esoterica, the secret died with him.

As Henry said, "The learned societies in this country have not the means, except in a very limited degree, of publishing memoirs which require expensive illustrations, much less of assisting to defray the cost of investigations by which the results have been attained." Henry felt, therefore, that the Smithsonian could make a real contribution to science by allotting a part of its income to such publication, and he provided for this in his initial program. "The publication of original memoirs and periodical reports," he said, "will act as a powerful stimulus on the latent talent of our country, by placing in bold relief the real laborers in the field of original research, while it will afford the best materials for the use of those engaged in the diffusion of knowledge." This program was immediately initiated, and Henry through the Smithsonian not only began a series of monumental publications but also organized a scheme (the International Exchange Service) by which scholarly publications in general could be distributed throughout the world.

Geology benefited tremendously, as did anthropology, astronomy, mathematics, biology, and other disciplines. The quarto volumes of the Smithsonian Contributions to Knowledge began to appear in the libraries and laboratories of the learned world, their large illustrations, ample print, and careful editing distinguishing them. Before 1860 there had appeared such pioneer works as Joseph Leidy's *Ancient fauna of Nebraska*; J. W. Bailey's *Microscopical examinations of soundings, made by the United States Coast Survey off the Atlantic coast of the United States*; and Edward Hitchcock's *Illustrations of surface geology*. There followed such works as Meek and Hayden's *Paleontology of the Upper Missouri* (1865); Charles Whittlesey's *On the fresh-water glacial drift of the Northwestern States* (1866); Raphael Pumpelly's *Geological researches in China, Mongolia, and Japan* (1866); J. G. Barnard's *On the internal structure of the earth* (1877); and many others.

The effect of these publications was indeterminable but pervasive, and over the years the Smithsonian's publications in geology, in all its branches, have constituted perhaps the greatest contribution of the Institution to that science. It did not, of course, end with the cessation of the Smithsonian Contributions to Knowledge in 1916, but has continued to the present day in other Smithsonian series, particularly the Smithsonian Miscellaneous Collections and the Bulletins of the United States National Museum.

One should mention here too, the free public lectures that Joseph Henry rather reluctantly inaugurated in the early days of the Smithsonian and which had their special heyday up to the time the Institution's lecture-room was destroyed by the fire in the Smithsonian Building in 1865. The best scientific and literary talent of the country was brought to Washington for these lectures, and geology was well represented. The very first lectures given in the Smithsonian Building were a series of six on *Geology*, by Edward Hitchcock, president of Amherst College. Other geological lecturers included the elder Benjamin Silliman and James D. Dana of Yale; Joseph LeConte, then of Georgia; T. Sterry Hunt, of Canada; Fairman Rogers, of Philadelphia; and Louis Agassiz, of Harvard. To quote again Professor Rice: "When science had scarcely naturalized itself in the country, these lectures in the national capital, and under quasi-authoritative auspices, served a most valuable purpose in stimulating public interest in scientific subjects."

The United States National Museum is the largest of the "bureaus" of the Federal Government administered by the Smithsonian. Its Department of Geology, housed in the Smithsonian's Natural History Building, is the Nation's great geological depository, and has been ever since 1846, when by act of Congress the custody of the National Cabinet of Curiosities was transferred to the Smithsonian Institution. The act stipulated that "all objects of natural history, plants, and geological and mineralogical specimens belonging or hereafter to belong to the United States," and which were then in the City of Washington, should be delivered to the Regents of the Smithsonian Institution and together with new specimens obtained by exchange, donation, or other-

wise, should be so arranged and classified as best to facilitate their examination and study. An act of March 3, 1879, decreed that "all collections of rocks, minerals, soils, fossils, and objects of natural history, archeology, and ethnology, made by the Coast and Geodetic Survey, the Geological Survey, or by any other parties for the Government of the United States, when no longer needed for investigations in progress, shall be deposited in the National Museum." By the operation of these authorities, augmented by the efforts of the National Museum's staff geologists, the national collections in geology have grown in all divisions—vertebrate paleontology, invertebrate paleontology, paleobotany, micropaleontology, petrology, mineralogy. Indeed, in some fields, such as Foraminifera, they are matchless anywhere in the world. Scientists from all over the world have studied these collections, and hundreds of technical papers based on them have been published, particularly in taxonomic paleontology. Many eminent geologists, such as William Henry Holmes, O. C. Marsh, Charles A. White, George Perkins Merrill, and Charles D. Walcott, have identified themselves with this Department of Geology of the Museum. The last-named, in fact, became the third Director of the United States Geological Survey and later the fourth Secretary of the Smithsonian Institution. His influence on American geology, both scientific and philanthropic, has been great and would make an interesting story in itself.

And another result of these Museum collections that we have been discussing is an educational one. The collections have been drawn upon through the years as the basis of geological exhibits that have been viewed by millions of people. Today this exhibition phase is being developed to a high level in the modernized and expanded displays that are being built, a most notable example being the new Gems and Minerals Hall opened to the public in July 1958. We surmise that James Smithson would be surprised but pleased if he could walk into this hall today, captioned by his name on a block of smithsonite. Perhaps, however, we are getting away from our limitation of "early American geology."

In summary, then, we should say that during the third of a century between the establishment of the Smithsonian Institution 1846 and the founding of the United States Geological Survey in 1879, the Smithsonian served as a focus, headquarters, and catalyst for geology in America. Its contribution to the science of geology was manifested along several lines: (1) the encouragement, stimulation, and facilities offered by the Institution to young scientists who gathered in Washington in those early days; (2) the publication and worldwide distribution of geological works at a time when expensive monographic publication was difficult to obtain; (3) aid that the Smithsonian rendered in the western explorations and surveys; (4) its promotion of the science of paleontology and its necessary concomitant, taxonomy; (5) the building up of the great geological collections in the U. S. National Museum; and (6) education in geology through the Museum exhibits emanating from these collections.

REFERENCES

BASSLER, RAY S. *The Smithsonian: Pioneer in American geology.* Science **104** (2693): 125–129. 1946.

GILMORE, CHARLES W. *A history of the division of vertebrate paleontology in the United States National Museum.* Proc. U. S. Nat. Mus. **90**: 305–377. 1941.

JAMES, JAMES ALTON. *The first scientific exploration of Russian America and the purchase of Alaska.* Northwestern Univ. Studies in Social Sci. **4**: 276 pp. 1942.

MERRILL, GEORGE PERKINS. *Contributions to the history of American geology.* Rep. U. S. Nat. Mus. for 1904: 189–733, illus. 1906.

OEHSER, PAUL H. *Sons of science: The story of the Smithsonian Institution and its leaders:* xvii + 220 pp., illus. New York, 1949.

RICE, WILLIAM NORTH. *Geology and mineralogy.* In "The Smithsonian Institution, 1846–1896: The History of its First Half Century," edited by George Brown Goode: 631–646. Washington, 1897.

SMITHSONIAN INSTITUTION. *Annual reports of the Board of Regents,* 1847–1878.

UNITED STATES CONGRESS. *A memorial of Joseph Henry:* 528 pp. Washington, 1880. (Published also in Smithsonian Misc. Coll. **21**: 1879.)

Geology Plus Adventure: The Story of the Hayden Survey

By J. V. Howell, *Tulsa, Okla.*

The period 1840 to 1880 was one of expansion on a scale never before experienced in North America. Population density of the area east of the Missouri had reached a point at which the supply of cheap land was near exhaustion as a result of 250 years of exploration and settlement. Yet the desire for land and the spirit of adventure were in no wise diminished, and the stage was set for the explosive westward movement which, in 35 years, resulted in settlement of all that area from the Missouri River to the Pacific.

Transportation here was a problem vastly different from that in the eastern half of the country, where rivers, lakes, and mountain passes were readily traversed, wood was generally available for fuel, pastures were plentiful, and the Indians were soon conquered or driven to the northward and southward. But on the Western plains the streams were few and seasonal and flowed in the wrong direction. The Indian tribes were warlike and well mounted, and main trails were lacking. Nevertheless, the feat was accomplished, and in a remarkably short time.

First, as usual, came the fur traders and trappers; then the military explorations with their emphasis on wagon roads and railroad routes to the Pacific, and with them the geological and natural history surveys. In seeking a reason for their proliferation, one needs only to consider the temper of the people and the reasons cited above. Both government and its citizens were avid for news of the West.

Alone of all the various explorations of the period, the Hayden Survey and its immediate predecessors, staffed by Ferdinand V. Hayden and a handful of assistants, have failed to receive full recognition and adequate description. Meanwhile, those of King, Powell, Frémont, Gunnison, Marcy, Long, and others have produced a spate of books. For this there are many reasons, none of which seems wholly justified. The last four were Army expeditions, each assigned to the search for a major route to the Pacific. Geology and natural history were secondary to pathfinding, the civilian scientists being strictly subordinates. King's Survey of the 40th Parallel gained prestige and acclaim not only by reason of its undisputed geological results but also because of its colorful, articulate leader. That of Powell became famous first through the impact of the Grand Canyon Voyage, the adventurous character of which largely overshadowed its very real geological discoveries. Hayden, on the other hand, had little flair for personal publicity and depended on a workmanlike job, prompt publication of results, and an efficient liaison with the newspapers to publicize his expeditions.

Ferdinand V. Hayden was born in Westfield, Mass., on September 7, 1829, to Asa and Melinda Hawley Hayden, and he lived there until his twelfth year. At this time his parents separated, the father moving to Rochester Depot, Ohio, and the mother to Rochester, N. Y. Each remarried and each had children by the second spouse. Ferdinand lived with an uncle at Rochester Depot, and at the age of 18 entered Oberlin College, 15 miles distant, from which he was graduated in the spring of 1850. He then entered Albany Medical College where he came under the influence of James Hall and of Dr. J. S. Newberry, who combined the practice of medicine in Cleveland, Ohio, with the study of paleobotany.

It should be mentioned here that only through a medical course could the student of that day obtain an adequate training in science. Hayden seems to have had no urge to practice medicine and never did so, except during the Civil War, when he served as a surgeon in the Union Army. Shortly before graduation in 1853, Hayden, sponsored by James Hall, made a trip up the Missouri Riven in search of vertebrate fossils in the Badlands. In this venture he was joined by F. B. Meek, and thus began an association that ended only with Meek's death in 1876.

The complete story of Hayden and the Hayden Survey has never been told and is

beyond the scope of this paper. But an appraisal of the work is possible, and many hitherto unemphasized features will be pointed out. Previous authors, concerned with Hayden's rivals, have been careless in their statements, and some of these, too, will be refuted.

After their first trip up the Missouri, an expedition financed by James Hall and by Pierre Chouteau, Jr., Alex Culbertson and J. B. Sarpy of the American Fur Co., Meek and Hayden returned in late autumn and spent the winter at Albany, preparing their collections and writing a report.

In the spring of 1854, Hayden again ascended the Missouri under the auspices of the American Fur Co. and Maj. A. J. Vaughan, the Indian agent for the Upper Missouri tribes. This time he remained through the winter, living at Fort Pierre and making trips as weather permitted. During this period he was able to visit the posts at Forts Sarpy, Benton, and Union, returning to St. Louis on November 5, 1855.

In 1856, attached to the exploring party of Lt. G. K. Warren, Hayden again ascended the Missouri, traveling upriver by steamer, and visited the valley of the Yellowstone, part of the time in company with the famous guide Jim Bridger.

Again in 1857, he accompanied Lieutenant Warren to the Black Hills and for the first time discovered their domal structure. Writing to Prof. S. F. Baird from Fort Laramie on August 21, he said, "Success has attended all our efforts, but we have had a hard time. My discoveries in a geological way are wonderful," and "I have got the key to the mountain area," and "I am making good use of it, so that this trip will not by any means be a failure."

The following year, 1858, under the auspices of the Department of the Interior (General Land Office), and with an appropriation of $5,000, Hayden made a survey of western Kansas, traveling by wagon and on horseback. In 1859–60 he was attached to the expedition led by Col. W. F. Raynolds to the headwaters of the Missouri and Yellowstone Rivers. This party wintered at Deer Creek, Wyoming (½ mile southwest of Glenrock), and under the guidance of Jim Bridger made an unsuccessful attempt to reach the geyser area of the Yellowstone. Bridger had been with the party during most of its travels, and there is no doubt that Hayden was well acquainted with the "tall tales" of that famous raconteur. Certain it is that on the 1871 expedition the route taken to the Park area followed that of the 1860 attempt which had been foiled by the deep snow in the mountain passes.

The Civil War brought to a close all Western explorations, and Hayden entered the Army as acting assistant surgeon, was advanced to surgeon of volunteers, and was discharged with the rank of brevet lieutenant colonel on June 22, 1865. His Army service involved duty in hospitals at Beaufort, S. C.; West Philadelphia, Pa.; and Winchester Field Hospital at Winchester, Va.

Immediately after his discharge from the Army, Hayden again headed for the Upper Missouri, this time with one assistant and under the auspices of the Academy of Natural Sciences of Philadelphia. Starting from Fort Randall, S. Dak., on August 3, he made a circuit of 650 miles in 52 days, his party consisting of James Stevenson, a guide, an Indian hunter, and a military escort of five troopers.

The years 1867–68, Hayden, under auspices of the General Land Office, devoted to a survey of Nebraska Territory and eastern Wyoming, but he was able to make trips into North Park, Colorado, and westward along the Union Pacific Railroad almost to Salt Lake City and to spend two weeks in the San Luis Valley. All this travel was on foot or on horseback.

In the year 1869, again under the General Land Office, Hayden traveled from Cheyenne southward along the foothills to Santa Fe, returning through South, Middle, and North Parks. As a result of this trip he was able to state for the first time that (1) the main range of the Rockies is a huge anticlinal; (2) the Tertiary Lignite beds from New Mexico to Canada are parts of one basin, interrupted by uplifts; (3) the Rocky Mountains are Post-Cretaceous in age; and (4) the lower ranges are monoclinal, descending toward the plains in steps.

By this time he had seen much of the present States of Montana, North and South Dakota, Wyoming, Kansas, Nebraska, and northeastern Utah. A "Grand Plan" was now shaping up, which involved the map-

ping of these States as a unit, embracing the mountains and plains, and studying the relationships between them. With the reconnaissance completed, detailed study and mapping were now the object of his efforts.

In 1870 there was created, under the Department of the Interior, the U. S. Geological and Geographical Survey of the Territories with Hayden as director. The work of the first year was in Wyoming, the starting point Cheyenne, and, with an appropriation of $25,000, it was possible to utilize 12 assistants, 8 teamsters and cooks, and sufficient horses and wagons. In this season Hayden first described and named the Dacota, Fort Pierre, and Fox Hills units of the Cretaceous.

The next year, 1871, the expedition took the field at Ogden, Utah, to which the tracks of the Union Pacific Railroad had then been extended. An appropriation of $40,000 permitted an increase in personnel to 32 and included the photographer W. H. Jackson and the artist Thomas Moran, and the summer was spent in what is now Yellowstone Park. Paintings and photographs resulting from their work were widely circulated and certainly aided greatly in obtaining increased support for the succeeding year. Incidentally, the edition of 12,000 copies of the 1871 report was exhausted by 1874.

The season of 1872 was spent in the Yellowstone Park area where two large parties totaling 56 men, 117 horses and mules, and 5 guests were able to explore thoroughly the valleys of the Yellowstone, Gallatin, Madison, and Snake Rivers and the Teton Mountains. There is little doubt that the photographs and reports of this year did much to cause the establishment of the Park.

Indian troubles in Wyoming led the War Department to forbid geological work there in 1873, and so attention was directed to Colorado, where three divisions covered Middle Park, South Park, and the San Luis Valley. In this year also triangulation and topography were begun under James T. Gardiner, previously associated with Dr. J. D. Whitney on the Survey of California. Again in 1874, 1875, and 1876 work was continued in Colorado and resulted in the great Atlas of the geology of that State, published in 1877, as well as the usual annual reports.

In general, Hayden's relations with the Indians were good, but the large Survey parties on occasion proved an irresistible temptation. Thus in 1872 a party had some difficulty with Bannocks near Fort Hall. In 1875 a party under J. T. Gardiner lost most of their animals and equipment near the Sierra La Sal after holding off an attack for several hours and finally escaping during the night. Meanwhile, W. H. Holmes lost his animals to a band of Utes on Montezuma Creek in southwestern Colorado. Holmes and his packer, Tom Cooper, pursued the Indians and recovered their stock on Recapture Creek, so named by Holmes in commemoration of this episode.

Again in 1877, A. D. Wilson's party in the Yellowstone area lost all their stock, apparently to Chief Joseph's band, while in the final year of 1878 a topographical party in the Teton area lost all its animals and part of its equipment. Several other minor attacks were repelled and no losses occurred, but diaries and letters of the period 1870–78 indicate that all parties posted guards each night in strict military fashion. Incidentally, a goodly number of the packers and guides were familiar with the Indian type of warfare, and a considerable number of packers, cooks, geologists, and topographers were veterans of the Civil War; and pictures, letters, and diaries agree that Hayden was the only one who habitually went unarmed.

In 1877, work again was in Wyoming, Utah, and Idaho but was rudely interrupted in September by the depredations of Chief Joseph. Next season an attempt was made to conclude the work in the Wind River and Yellowstone areas, and the personnel numbered 68. Despite loss of all the horses of the Yellowstone party, much was accomplished, particularly by A. C. Peale and W. H. Holmes in the Park area.

On June 30, 1879, the Hayden Survey ended. Hayden himself moved to Philadelphia where he owned a home, where his wife's family lived, and where there was access to library facilities then superior to those in Washington. Here he closed out the Survey affairs and completed his 2-volume final report. By now his health had begun to fail, and although in the summers of 1883–1886 he made several trips to Mon-

tana with his close friend Peale, his condition grew rapidly worse, and he died in December 1887.

It may be of interest to note that on December 30, 1930, six surviving members of the Hayden Survey, W. H. Holmes, George B. Chittenden, Ernest Ingersoll, W. H. Jackson, Story B. Ladd, and Frederick D. Owen, met in Washington to unveil a memorial to the Survey. This took the form of a bronze plaque located in the ground-floor lobby of the new Washington Evening Star Building, at the corner of Eleventh Street and Pennsylvania Avenue, NW., site of the old Star Building on whose third floor were the offices of the Survey from 1870 to 1875.

An institution should be judged by the quantity and quality of its work, and in this respect the Hayden Survey and its director have not received adequate recognition. One may look well at the "firsts" attributed to them, as follows:

1. Developed the plan of having topographer and geologist work together, a method carried over to the U.S.G.S. and continued down to the recent past.
2. First reported the domal structure of the Black Hills.
3. Made the first scientific exploration of the Yellowstone Park.
4. First determined age of the Rocky Mountains.
5. First reported presence of Potsdam sandstone west of the Missouri.
6. Made the first geological map of the Black Hills.
7. First to report thrusting in the Rockies.
8. First to delimit and name 29 stratigraphic units of the Cretaceous and Tertiary of the Western United States, which are still valid and used in their original sense.
9. First to recognize and explain the terraces in the Salt Lake Basin (in 1869).
10. First to recognize and explain laccoliths (but not to name them).
11. First to point out the anticlinal structure of the Main Range of the Rockies.
12. First to make extensive use of photographs to illustrate geologic features.
13. First to show the existence of the great Tertiary basin extending from Mexico to Canada.

Other features that should be noted include Hayden's invariable custom of publishing the report of one season's work before taking the field for the following year. No backlog of manuscripts was allowed to accumulate. And here it may be well to point out that the Survey during the nine years of its existence published 21,142 pages of reports, while Hayden alone, or with F. B. Meek, published a grand total of 1,306 pages bearing his name.

During these same 25 years from 1853 to 1878 there were employed 14 geologists (including Hayden) whose total man-years of field work were 55 in number. The area mapped by all Hayden expeditions and colored on the final map of 1882 included 417,000 square miles, which indicates an output of 7,582 square miles per man—per year. Admittedly, this was largely reconnaissance, but the work was good to excellent and shows everyone was working.

Other statistics concerning personnel may be of interest also. Of 219 members of Hayden's various expeditions, 38 are listed in Who Was Who, Dictionary of American Biography, and American Men of Science. Approximately 70 streams, mountains, towns, lakes, and gulches were named for Survey members. At least 10 men wrote books other than technical reports, and one became a Congressman. Eighteen employees, after the Survey closed, joined U.S.G.S. or other Government departments.

Here may be mentioned a feature of the personnel which was much criticized by his opponents. This pertained to Hayden's employment each season of a few "general assistants" who were sons, nephews, or protegees of Senators and Congressmen. Recalling that there was then no Civil Service, that Hayden's relations with Congress were generally good, and that most of these assistants were college students or graduates and did a man's work, in addition to having a great adventure, one cannot be too critical. Besides, what else could Hayden do if, as is shown by the record, one application was signed by 32 Senators and Congressmen! Incidentally, this young man wrote a very creditable book for boys detailing his experiences of that summer. It is entitled *In the trail of the pack-mule*, and the author is Sid H. Nealy, who was an assistant in 1872 and 1873.

The Hayden Survey, its members and Hayden himself, left behind a vast store of nearly 12,000 unpublished letters, diaries, and journals, scattered widely. No full biography of Hayden, or a history of his Survey, has yet been published. However, Dr. F. M. Fryxell and the writer, after many years of searching, have brought all this together on microfilm or photostatic copy; and they hope eventually to write the detailed history which the man and his Survey deserve. The story is one that will require a large volume, and in this brief paper only a glimpse can be given of geology plus adventure as revealed by the participants themselves.

A History of the Popularization of Geology in America: A Bibliographical Survey

By Mark W. Pangborn, Jr., *U. S. Geological Survey*

The history of the public relations aspects of our science reveals that in this country, during the 1830's and 1840's, geology held a high position in public esteem, that our profession lost that position by default, and that, by the same token, it is reestablishing geology as a subject worthy of strong public support and interest, and that an effective and abundant popular literature plays a large role in such a rennaissance.

During the Colonial and early Federal periods the study of geology was largely limited to the educated aristocracy. Such public figures as Jefferson and Gallatin were considerable students of geology, and their interests were often parlayed into worthy public enterprises, such as the explorations of Lewis and Clark, Pike, and Long.

It was in the 1830's and 1840's, however, that geology really came into its own. This was the great age of the lyceum, or public lecture series, that so impressed Agassiz when he arrived in Boston in 1846. Geology rode high on the wave of self-culture and interest in natural history that got under way about 1820, propelled by the ardent proselyting activities of a sizable percentage of the most prominent geologists, including Eaton, Silliman, H. D. Rogers, Lyell, and Agassiz. Amos Eaton alone made 3,000 lectures outside the classroom, and it was in part due to the boundless enthusiasm of such men that a number of State legislatures were inspired to finance early surveys.

The layman's literature of the time was largely that used by the geologists themselves. Concepts were still simple, and the specialized geological terminology of 1840 was limited to a few hundred words. The textbooks of Eaton (1), J. D. Dana (2), Hitchcock (3), and Lyell (4) sold well among those hungry for learning, and Mantell's *Medals of creation* (5) and Hugh Miller's *Old Red Sandstone* (6) were vastly popular informal books. The volumes of the early State surveys were also well received by laymen. Yet even this enlightened age had its share of potboilers by nongeologists, and we must admit that the works of S. G. Goodrich (Peter Parley) are horrible examples of the genre.

Public interest in geology declined during the period from the Civil War to the turn of the century, despite interest in the great bonanzas and in Western exploration. Part of the decline may be blamed on the fact that during this period geologists began to use their special and often unnecessary technical terms, a trend which continues to the present day and renders unacceptable, to the layman, far too much of the professional literature. Equally significant was the very sharp decline in the proportion of geologists interested in popularizing their science.

Some of the most famous exceptions were, of course, John Wesley Powell and Clarence King. *Exploration of the Colorado* (9) and *Mountaineering in the Sierra Nevada* (8) went through many editions and helped to keep alive the tradition of Western scientific exploration. Perhaps the biggest selling book was Darwin's *Origin of species* (7),

which caused almost as much uproar and intellectual ferment in this country as it did in England. Other geologist-writers included J. D. Dana, whose easier texts, like *The geological story briefly told* (12), were fine for high school and layman's use, and N. S. Shaler, who turned out a number of nontechnical introductions to physiography, such as *Aspects of the earth* (10) and *Sea and land*. Another gifted popularizer was Alexander Winchell, whose vividly written *Walks and talks in the geological field* (11) was, for many years, on the reading list of the Chautauqua Association, an organization whose subscribers numbered 5 million in the year 1900. Among nongeologist writers, the best was probably H. N. Hutchinson, a liberal English clergyman whose books *Extinct monsters* (13) and *Creatures of other days* were free of the theological controversy of earlier times.

From 1900 to World War II, it is no coincidence that geology and physiography all but disappeared from the high schools at the same time that interest in popularization all but disappeared within our profession.

On the credit side, between 1910 and 1930 the U. S. Geological Survey undertook a modest public education program, publishing guidebooks (14) covering some of the western railroad routes, and some booklets on the national parks, by men like Arnold Hague, M. R. Campbell, and W. T. Lee. François Matthes, in his *Geologic history of the Yosemite Valley* (17), proved that a scientific classic could be written in plain English. The National Park Service became a potent educational force in the 1920's as its public education program began to develop. Some State surveys, notably New York, Pennsylvania, and Kentucky, began to issue popular publications, as did the American Museum of Natural History. Popular interest in mineral collecting, to become so strong in the 1950's, began to revive with the founding of the journals Rocks and Minerals, in 1926, and Mineralogist, in 1933.

Among the few layman's books that sold well were F. B. Loomis's *Field book of common rocks and minerals* (15) and astronomer W. M. Reed's *The earth for Sam* (16). Two other authors, who are still turning out big sellers, were Roy Chapman Andrews, whose books on dinosaur hunting (19) were well received, and Carroll Lane Fenton, who was establishing his reputation as a popularizer with works like *Our amazing earth* and *The rock book* (18).

Since World War II, the outlook for popularizing geology has become generally brighter. Geology courses are being reintroduced into a number of high schools, and school libraries, by now rather common, feature the better-known geological texts and popular works, as well as such fine journals as Natural History and Scientific American. Some States have stepped up their educational and publishing programs, including California (22), Kansas, Oklahoma, and Illinois, and the U. S. Geological Survey now prints geological descriptions on the backs of its National Parks maps (23).

The National Park Service remains preeminent as the great popularizer of geology in the country. Perhaps 10 million young people of school age see geological wonders first hand every year, and take home scores of thousands of earth science books from park concessions.

Interest in caves has burgeoned since 1941, when the National Speleological Society was formed; now its 1,700 members and perhaps 15,000 other young spelunkers spend their weekends underground. Even more spectacular has been the spread of interest in mineral collecting and cutting; H. C. Dake authoritatively estimates the minimum number of devotees at 250,000.

With the publication of the successful new Merit Badge pamphlet on geology (27), the Boy Scouts have become an important agent for promoting the earth sciences. Over 50,000 copies of this pamphlet have been sold since introduction in 1953, and geology badges earned have risen from 300 to 3000 per year. Geology month among the Scouts, October 1957, featured "The biggest show on earth," during which 4,000 geologists assisted 38,000 scout units to make it by far the largest public relations program ever put on by our profession.

Geology now has an over-all public relations organization in the American Geological Institute, founded in 1948. Its publications include a career booklet, of which a modest 18,000 copies have been given away, and a layman's guide to the nontechnical

The Hayden Survey, its members and Hayden himself, left behind a vast store of nearly 12,000 unpublished letters, diaries, and journals, scattered widely. No full biography of Hayden, or a history of his Survey, has yet been published. However, Dr. F. M. Fryxell and the writer, after many years of searching, have brought all this together on microfilm or photostatic copy; and they hope eventually to write the detailed history which the man and his Survey deserve. The story is one that will require a large volume, and in this brief paper only a glimpse can be given of geology plus adventure as revealed by the participants themselves.

A History of the Popularization of Geology in America: A Bibliographical Survey

By Mark W. Pangborn, Jr., *U. S. Geological Survey*

The history of the public relations aspects of our science reveals that in this country, during the 1830's and 1840's, geology held a high position in public esteem, that our profession lost that position by default, and that, by the same token, it is reestablishing geology as a subject worthy of strong public support and interest, and that an effective and abundant popular literature plays a large role in such a rennaissance.

During the Colonial and early Federal periods the study of geology was largely limited to the educated aristocracy. Such public figures as Jefferson and Gallatin were considerable students of geology, and their interests were often parlayed into worthy public enterprises, such as the explorations of Lewis and Clark, Pike, and Long.

It was in the 1830's and 1840's, however, that geology really came into its own. This was the great age of the lyceum, or public lecture series, that so impressed Agassiz when he arrived in Boston in 1846. Geology rode high on the wave of self-culture and interest in natural history that got under way about 1820, propelled by the ardent proselyting activities of a sizable percentage of the most prominent geologists, including Eaton, Silliman, H. D. Rogers, Lyell, and Agassiz. Amos Eaton alone made 3,000 lectures outside the classroom, and it was in part due to the boundless enthusiasm of such men that a number of State legislatures were inspired to finance early surveys.

The layman's literature of the time was largely that used by the geologists themselves. Concepts were still simple, and the specialized geological terminology of 1840 was limited to a few hundred words. The textbooks of Eaton (1), J. D. Dana (2), Hitchcock (3), and Lyell (4) sold well among those hungry for learning, and Mantell's *Medals of creation* (5) and Hugh Miller's *Old Red Sandstone* (6) were vastly popular informal books. The volumes of the early State surveys were also well received by laymen. Yet even this enlightened age had its share of potboilers by nongeologists, and we must admit that the works of S. G. Goodrich (Peter Parley) are horrible examples of the genre.

Public interest in geology declined during the period from the Civil War to the turn of the century, despite interest in the great bonanzas and in Western exploration. Part of the decline may be blamed on the fact that during this period geologists began to use their special and often unnecessary technical terms, a trend which continues to the present day and renders unacceptable, to the layman, far too much of the professional literature. Equally significant was the very sharp decline in the proportion of geologists interested in popularizing their science.

Some of the most famous exceptions were, of course, John Wesley Powell and Clarence King. *Exploration of the Colorado* (9) and *Mountaineering in the Sierra Nevada* (8) went through many editions and helped to keep alive the tradition of Western scientific exploration. Perhaps the biggest selling book was Darwin's *Origin of species* (7),

which caused almost as much uproar and intellectual ferment in this country as it did in England. Other geologist-writers included J. D. Dana, whose easier texts, like *The geological story briefly told* (12), were fine for high school and layman's use, and N. S. Shaler, who turned out a number of nontechnical introductions to physiography, such as *Aspects of the earth* (10) and *Sea and land.* Another gifted popularizer was Alexander Winchell, whose vividly written *Walks and talks in the geological field* (11) was, for many years, on the reading list of the Chautauqua Association, an organization whose subscribers numbered 5 million in the year 1900. Among nongeologist writers, the best was probably H. N. Hutchinson, a liberal English clergyman whose books *Extinct monsters* (13) and *Creatures of other days* were free of the theological controversy of earlier times.

From 1900 to World War II, it is no coincidence that geology and physiography all but disappeared from the high schools at the same time that interest in popularization all but disappeared within our profession.

On the credit side, between 1910 and 1930 the U. S. Geological Survey undertook a modest public education program, publishing guidebooks (14) covering some of the western railroad routes, and some booklets on the national parks, by men like Arnold Hague, M. R. Campbell, and W. T. Lee. François Matthes, in his *Geologic history of the Yosemite Valley* (17), proved that a scientific classic could be written in plain English. The National Park Service became a potent educational force in the 1920's as its public education program began to develop. Some State surveys, notably New York, Pennsylvania, and Kentucky, began to issue popular publications, as did the American Museum of Natural History. Popular interest in mineral collecting, to become so strong in the 1950's, began to revive with the founding of the journals Rocks and Minerals, in 1926, and Mineralogist, in 1933.

Among the few layman's books that sold well were F. B. Loomis's *Field book of common rocks and minerals* (15) and astronomer W. M. Reed's *The earth for Sam* (16). Two other authors, who are still turning out big sellers, were Roy Chapman Andrews, whose books on dinosaur hunting (19) were well received, and Carroll Lane Fenton, who was establishing his reputation as a popularizer with works like *Our amazing earth* and *The rock book* (18).

Since World War II, the outlook for popularizing geology has become generally brighter. Geology courses are being reintroduced into a number of high schools, and school libraries, by now rather common, feature the better-known geological texts and popular works, as well as such fine journals as Natural History and Scientific American. Some States have stepped up their educational and publishing programs, including California (22), Kansas, Oklahoma, and Illinois, and the U. S. Geological Survey now prints geological descriptions on the backs of its National Parks maps (23).

The National Park Service remains preeminent as the great popularizer of geology in the country. Perhaps 10 million young people of school age see geological wonders first hand every year, and take home scores of thousands of earth science books from park concessions.

Interest in caves has burgeoned since 1941, when the National Speleological Society was formed; now its 1,700 members and perhaps 15,000 other young spelunkers spend their weekends underground. Even more spectacular has been the spread of interest in mineral collecting and cutting; H. C. Dake authoritatively estimates the minimum number of devotees at 250,000.

With the publication of the successful new Merit Badge pamphlet on geology (27), the Boy Scouts have become an important agent for promoting the earth sciences. Over 50,000 copies of this pamphlet have been sold since introduction in 1953, and geology badges earned have risen from 300 to 3000 per year. Geology month among the Scouts, October 1957, featured "The biggest show on earth," during which 4,000 geologists assisted 38,000 scout units to make it by far the largest public relations program ever put on by our profession.

Geology now has an over-all public relations organization in the American Geological Institute, founded in 1948. Its publications include a career booklet, of which a modest 18,000 copies have been given away, and a layman's guide to the nontechnical

literature (29). Yet A.G.I.'s operations are still on a small scale compared with those of the American Petroleum Institute and of certain oil companies, which distribute free career materials and teachers' pamphlets by the millions.

In the past few years there has been a noticeable increase in the sales of popular geology books, both absolute and in relation to other technical subjects; only aviation and rocketry attract more young readers now than do the earth sciences. The Fentons' *Rock book*, for example, has been selling twice as well since 1945 as it did when published in 1940, and Zim and Shaffer's new *Rocks and minerals* (30) is the runaway leader in the fabulously successful Golden Guide series.

In addition to established names like Andrews (25) and the Fentons (31), a new group of outstanding popularizers is now at work. Among them are journalist Ruth Moore (28), physicist George Gamow (21), geologists O. P. Jenkins (22) and F. M. Fryxell, paleontologists G. G. Simpson and E. H. Colbert (20), and mineralogists R. M. Pearl (26) and F. H. Pough (24).

Although lack of objective data makes it difficult to contrast the status of popular geology in recent years with its status in the 1840's, it is clear that in 1840 a high percentage of the most prominent geologists participated in public lectures and similar services; by 1940 surely no more than one or two percent of our profession lectured, counselled, or wrote for the public.

I am glad to say, however, that since World War II an increasing number of geologists have become aware that geology must be brought to the layman if public interest and support for geological enterprises are to grow, and if a supply of future geologists is to be assured. Let us hope that our profession fills the gaps in the popular literature. New illustrating and publishing techniques promise more attractive books, and new marketing methods are providing far wider audiences. If our geologists themselves can engender the proselyting enthusiasm of Amos Eaton and Agassiz, and are willing to grant their popularizations the same care that they put into their professional work, then geology will indeed hold the American public's interest and approval.

BIBLIOGRAPHY

1. EATON, AMOS. *Geological text book, prepared for public lectures on North American geology . . . :* 63 pp. Webster and Skinners, Albany, 1830.
2. DANA, JAMES DWIGHT. *A system of mineralogy:* 144 pp. Durrie & Peck, New Haven, 1837.
3. HITCHCOCK, EDWARD. *Elementary geology*, ed. 2: 346 pp. Dayton & Saxton, New York, 1841. (Went through 30 editions in 20 years; Hitchcock tried to reconcile the Bible and geology.)
4. LYELL, CHARLES. *Elements of geology*, 1st American ed. James Kay, Philadelphia, 1839. (Lyell's numerous textbooks went through many editions.)
5. MANTELL, GIDEON ALGERNON. *The wonders of geology*, 2 vols. A. H. Maltby, New Haven, 1839. (This and *Medals of creation* were intended for the layman.)
6. MILLER, HUGH. *The Old Red Sandstone*. Edinburgh, 1841.
7. DARWIN, CHARLES ROBERT. *Origin of species*, 1st American ed.: 432 pp. Appleton, New York, 1860. (Appleton issued this book in the face of hundreds of threatening letters; it was a best seller for years.)
8. KING, CLARENCE RIVERS. *Mountaineering in the Sierra Nevada*. J. R. Osgood, Boston, 1872.
9. POWELL, JOHN WESLEY. *The exploration of the Colorado River of the West . . . :* 291 pp. Government Printing Office, Washington, 1875.
10. SHALER, NATHANIEL SOUTHGATE. *Aspects of the earth:* 344 pp. Scribner, New York, 1889.
11. WINCHELL, ALEXANDER. *Walks and talks in the geological field:* 329 pp. Chautauqua Press, New York, 1886.
12. DANA, JAMES DWIGHT. *The geological story briefly told:* 302 pp. American Book Co., New York, 1895.
13. HUTCHINSON, HENRY NEVILLE. *Extinct monsters . . . :* 254 pp. Appleton, New York, 1892.
14. LEE, WILLIS THOMAS. *Guidebook of the Western United States, Part B, The Overland route . . . :* 244 pp. Government Printing Office, Washington, 1915. (U.S. Geol. Surv. Bull. 612.)
15. LOOMIS, FREDERIC BREWSTER. *Field book of common rocks and minerals:* 352 pp. Putnam, New York, 1923. (100,000 copies of this steady best seller have been printed over the years.)
16. REED, WILLIAM MAXWELL. *The earth for Sam:* 390 pp. Harcourt Brace, New York, 1930. (52,000 copies in print.)
17. MATTHES, FRANÇOIS EMILE. *Geologic history of the Yosemite Valley:* 137 pp. Government Printing Office, Washington, 1930. (U.S. Geol. Surv. Prof. Paper 160.)
18. FENTON, CARROLL LANE, and FENTON, M. A. *The rock book:* 357 pp. Doubleday, New York, 1940. (Over 40,000 copies sold.)
19. ANDREWS, ROY CHAPMAN. *Under a lucky star; a lifetime of adventure:* 300 pp. Viking, New York, 1943. (Sold 30,000.)

20. COLBERT, EDWIN HARRIS. *The dinosaur book:* 156 pp. American Museum of Natural History, New York, 1945. McGraw-Hill, 1951. (Nearly 25,000 copies of this model popularization have been bought.)
21. GAMOW, GEORGE. *Biography of the earth:* 194 pp. Viking, New York, 1948. (8,000 of the hard cover edition and a quarter million paperbacks have been sold.)
22. JENKINS, OLAF PITT. *Geologic guidebook along highway 49—Sierran gold belt . . . :* 164 pp. San Francisco, 1948. (California Div. Mines Bull. 141. Leads all state-issued publications with 20,000 copies sold.)
23. U.S. GEOLOGICAL SURVEY. *Topographic map of the Denver mountain area,* scale 1:190,680. Washington, 1948. (Top seller among Park maps which have a geological text on the back; over 3,000 per year.)
24. POUGH, FREDERICK HARVEY. *A field guide to rocks and minerals:* 333 pp. Houghton Mifflin, Boston, 1953. (Like Loomis, a tremendous seller.)
25. ANDREWS, ROY CHAPMAN. *All about dinosaurs:* 146 pp. Random House, New York, 1953. (A leader even in the highly successful "All-about" series of children's books, with sales over 160,000.)
26. PEARL, RICHARD MAXWELL. *How to know the minerals and rocks:* 192 pp. McGraw-Hill, New York, 1955. (Another title which has passed the quarter million mark, in all editions.)
27. BOY SCOUTS OF AMERICA. *Merit badge series: geology,* ed. 2: 35 pp. New York, 1956.
28. MOORE, RUTH. *The earth we live on:* 416 pp. Knopf, New York, 1956. (This history of geology has had a fine reception.)
29. PANGBORN, MARK W., JR. *Earth for the layman; a list of nearly 1400 good books . . . ,* ed. 2: 68 pp. Washington, 1957. (American Geol. Inst. Report no. 2.)
30. ZIM, HERBERT SPENCER, and SHAFFER, PAUL. *Rocks and minerals:* 160 pp. Simon & Schuster, New York, 1957. (Numerous sales outlets, high quality, and low price enable this title to sell at the rate of half a million copies per year, surely the all-time high for a science book.)
31. FENTON, CARROLL LANE, and FENTON, M. A. *The fossil book:* 496 pp. Doubleday, New York, 1958. (Prepublication orders of this expensive book totalled nearly 4,000, a phenomenon that could hardly have been conceived a few years ago.)

Asa Gray and American Geology

BY A. HUNTER DUPREE, *University of California*

American geologists as a group did not occupy a theoretical position which could help them much to understand what was happening when the *Origin of species* broke over them in 1859. In spite of their number and the quality of the precise stratigraphical work which they were doing, their theories were as crude as they were hotly contested within the group itself. As examples, the brothers William Barton Rogers and Henry Darwin Rogers will serve as well as any. They were able geologists, but their theories, depending heavily on such cataclysms as sudden floods, were far-fetched. Louis Agassiz had imported the idea of a glacial epoch to North America, but his ideas of organic development were dominated by an extreme idealism. Even the acclaim of Europe was not sufficient to establish his glacial hypothesis firmly in America, where many geologists still talked of icebergs as the main depositors of the drift. Virtually the only general theoretical agreement in American geology in 1859 was a propensity to catastrophism. The one man with the stature to resolve these difficulties and to bring American concepts into line with Darwinian theories, James Dwight Dana, did not perform this expected role both because his own thoughts on species were distinctly idealistic and because his health broke in 1859, preventing him from even reading the *Origin of species* for several years.

Within 15 years, or at the very most 20 years, the picture had changed completely. Not only did American geology stand near the forefront in its accomplishments, glorying and suffering in the great age of paleontology with O. C. Marsh and E. D. Cope, the glacial theories of T. C. Chamberlain, and the Great Basin studies of able men

such as G. K. Gilbert. Whatever theoretical difficulties remained, though they were formidable, were those which faced the men at the frontiers of the science rather than those of provincials caught in a backwater. Who was responsible for this sudden clearing of the ground, this rapid assimilation of descent with modification on the organic side of the geologic scale as required by Darwinian theory? Who dethroned the great catastrophist Louis Agassiz from the pinnacle of American geology in the very period that his glacial hypothesis was winning the vindication of overwhelming evidence? The answer to these questions is the name of a man who had the distinct advantage of knowing very little geology—the botanist Asa Gray.

While Gray's role as the protagonist of Darwin in America is widely if uncritically recognized, the specific contribution which he made toward adapting geologic phenomena to a Darwinian sequence of life forms has often been overlooked. And the implications which his work had for the reorganization of geologic theory among Americans have been almost totally ignored.

Gray began his scientific life in the late 1820's, when the old-style naturalist still had a place in the upstate-New York intellectual milieu in which he lived. Hence he collected, in addition to plants and insects, trilobites and minerals. His first paper in the American Journal of Science concerned the mineralogy of St. Lawrence County, N. Y. But Gray was a good example of a most important change which came across American science in the 1830's—the trend toward specialization. The old-style naturalist was vanishing, Gray becoming increasingly identified with the science of botany. Soon after he went to Harvard as Fisher Professor of Natural History he donated to the College his mineral collection in an almost symbolic act of renunciation.

That he had withdrawn from active research in any phase of geology made it easier for him to adopt general views of the subject without entering the controversies which raged among the professional geologists. Thus when Sir Charles Lyell lectured before the Lowell Institute in Boston in 1845, Gray attended regularly even though he considered Lyell "not a good lecturer at all." But he spoke of an Englishman "occupying—though under a rather different aspect the ground I am to take up . . . on Geographical Botany." Thus effortlessly and without fanfare Gray absorbed Lyell's point of view even if he did not use his opportunities to become a friend and correspondent of the British geologist.

Undoubtedly the arrival of Agassiz in America in 1846 stimulated Gray to a friendly reception of the Swiss scientist's glacial theory as well as his views on natural history. The two cooperated cordially to combat the idea of *Vestiges of the natural history of creation*, which had a considerable vogue in America as well as Europe. Yet even in 1846, subtle differences showed up between the thought of the two men, and Gray never assented either to Agassiz's idealistic views of species as "a thought of the Creator" or to his catastrophism.

By 1855 Gray was aware of a fundamental antagonism between his whole view of nature and that of Agassiz. Although the zoologist dominated the scene in America and commanded an overpowering European reputation, the quiet botanist had unusual facilities for tapping those minds of Europe who were shaping the coming revolution. He, and not Agassiz, was collaborating with Joseph D. Hooker and Alphonse De Candolle in creating a science of the geography of organisms on a world scale. Through Hooker he was brought into the circle of Charles Darwin, who might most aptly be described in 1855 as a geologist of first importance who had also prepared an admirable monograph on the barnacles. But behind the sharp questions concerning the world distribution of plants which Darwin put to Gray seemed to lurk a consistent set of doctrines. The trend of these doctrines, as they gradually became apparent in Darwin's letters, reinforced Gray's belief in the law of genetic connection among all the members of a species. They not only resembled one another, they were also the actual descendents from a single pair and had radiated from a single center of creation. Agassiz, on the other hand, maintained that species had been created in great numbers, occupying essentially the same geo-

graphic areas throughout their existence. Thus he denied both a genetic connection among the members of the same species and among similar organisms which occurred in different geologic strata. Gray increasingly felt dissatisfied with Agassiz's formulation, but until 1858 he bided his time, hoping to assemble a specific case with which to challenge his renowned colleague.

Gray found his facts with which to construct a challenge among the botanical collections coming in to him in large quantity from the American exploring expeditions, which were the characteristic research organizations of the 1850's. Disjunct distributions, that is, plants peculiar to two widely separated geographical localities, had been among the favorite arguments of those who believed in multiple as well as special creation. Gray found a large number of plants in the first collections to come in from Japan in 1857 and 1858 which were to be found also in eastern North America and nowhere else. To assume that a *Philadelphus*, say, which was reported only in Japan and the southern Appalachians, had been created in those two localities independently, seemed to Gray to answer the problem only by preventing its being posed. If he could, on the other hand, come up with a material connection between the two similar plants found half a world away, he would have a case which fairly refuted Agassiz's whole conception of biology.

The key to Gray's solution of the problem of disjunct distributions between eastern Asia and eastern North America lay in geology, and here his own ignorance placed him in the hands of others. Consulting both James Dwight Dana and Charles Darwin, he came up with a conception of geologic history which would explain the present distribution of plants. In the Tertiary period a temperate flora had extended all the way around the North Pole. With the glaciation of the Pleistocene epoch this flora had been pushed far southward, its remnants forming the disjunct distributions which Gray's evidence should. Thus a flora continuous across the Bering Strait area in the Tertiary provided a material and genetic connection between the plants with which Gray hoped to refute Agassiz. Gray had no fossil evidence of this Tertiary flora, and precious few indications of the climate, but his reasoning established an unbroken chain of events.

That his paper on this subject was intended as a full-scale assault on Agassiz and not a fragmentary report on collections from Japan is clear from the dramatic circumstances of that meeting of the American Academy of Arts and Sciences in Boston early in 1859, many months before the publication of the *Origin of species*. Agassiz was present in person to contest and rebut Gray's effort at every point. Yet the very construction of Gray's argument bears the marks of the debate. His strategy avowedly was to "hoist Agassiz on his own petard." At three points especially, this strategy led Gray to make choices momentous for American geology.

In the first place, he was one of the first Americans to accept publicly and unqualifiedly Agassiz's conception of the Ice Age. An ice sheet which spread generally over both the old and the new worlds was the agent which Gray needed to accomplish his distributions. It could not at the same time serve, however, as the catastrophe which Agassiz required. The very completeness of Gray's acceptance is a landmark in the history of glacial theory in America which must have infuriated Agassiz by its very cordiality.

In the second place, Gray was well aware that Agassiz, who believed that no Tertiary species existed in the present, would take advantage of Gray's lack of fossil evidence for a circumboreal temperate flora in the Tertiary. Agassiz had also made much of the length of time during which present species had remained unchanged. Therefore Gray, in choosing geologic advice, rejected that of Darwin in favor of Dana, who advocated a very warm period after the Pleistocene glaciation. Gray could thus postulate a second mingling of his species across the Bering Strait area after the Pleistocene as well as before, establishing a material connection even if one accepted with Agassiz the catastrophic nature of the Ice Age.

In the third place, Gray pointed out, besides the identical species which followed his pattern of distribution, a number of genera which did the same. Thus genera

peculiar to Eastern Asia and Eastern North America which were represented only by distinct species in the two places, suggested to Gray that the vicissitudes of geologic history had produced sufficient modifications in the pristine stock to lead to distinct species which nevertheless had descended from a single pair. This was descent with modification through geologic time, and lest anyone misunderstood the general bearing of his theories, he pointed to the Linnaean Society publication of 1858 which first presented Darwin and Alfred Russel Wallace to the world.

Agassiz never effectively answered Gray, despite his continued eminence in American science. When the *Origin of species* appeared, Gray introduced it to the American scientific public in a review in the American Journal of Science, speaking not for himself but for the whole board of editors, which included both Dana and Agassiz. When Gray retired as president of the American Association for the Advancement of Science in 1872 he presented his theories in new and elegant form in *Sequoia and its history*, which extended the formulation to Western North America. Before the end of his life in 1888 he was able to point to the research of Oswald Heer, Saporta, and others as providing fossil evidence from Arctic Tertiary flora to support his hypothesis.

Thus Gray, a botanist who knew little geology but only understood its implications, provided a secure base for a Darwinian geology in America even before the publication of the *Origin of species*. He ranged descent with modification in the organic scale alongside the geologic record and found in their coincidence a key to the present distribution of organisms. That Agassiz's whole conception of nature disappeared so promptly from American science, even among his own students, must be credited largely to Gray. At the same time, the equally rapid triumph of Agassiz's Ice Age theory received from the botanist a marked impetus. The Darwinian way of looking at the relation of geology and biology became common coin in America among geologists who never cited Gray in their publications. The very pervasiveness of this fundamental shift made it more anonymous.

Lest this sweeping conclusion be set down as the circumstantial adulation of a biographer, let me call your attention to a significant piece of contemporary evidence.[1] Of all those who commented on Gray's career at the time of his death in 1888, the one who most fully plumbed the significance of his introduction of organic evolution into geology was Lester Ward. As a paleobotanist, Ward is under a professional shadow because he spent so much of his time and intellect on sociology. But in 1888 Ward was speaking from the headquarters of American geology. As paleobotanist at the U. S. Geological Survey he was the fellow worker of John Wesley Powell, Gilbert, Clarence Dutton, and the rest.

Ward felt that "history will doubtless fully bear out the statement that, whether we look at England or to the United States, no man has done as much to remove apprehension from, and inspire respect for Darwinism, and therefore really to help its triumphal march, as the modest American botanist, Dr. Asa Gray." Concerning Gray's *Sequoia and its history*, Ward was even more specific. "Although possessed of scarcely any of the abundant facts of paleontology now known in support of his views, he saw with unerring ken and portrayed with a precision which had defied subsequent criticism, all the steps in the weary pilgrimage of these giant denizens of the Sierras, as they were driven southward by the advancing ice sheet, or lured northward by the return of cosmical summer . . . and he saw how, in this protracted and unequal struggle with the elements, this grand race of beings . . . had been gradually decimated in number and circumscribed in habitat . . ."

The idealist and catastrophic views of Agassiz, although not the influence of his magnetic personality, had so completely disappeared by 1888 that only a few could recognize in Gray a major actor at a crucial juncture in the history of science, a deft and able theoretician who with one thrust of his polished stiletto of a pen—the phrase is Darwin's—deflated one view of nature and aided in the substitution of another.

[1] WARD, LESTER F., *Asa Gray and Darwinism*. New Monthly Mag., August 1888: 85–92.

Darwinian Natural Selection and Vertebrate Paleontology

BY JOHN A. WILSON, *University of Texas*

The close correlation between form and function as seen by the vertebrate paleontologists in North America prevented the adoption of Darwin's proposal of natural selection as the primary operating force in evolution. This resulted in a schism between paleontologists and neontologists that did not close until the 1940's. Cope in the immediately post-Darwin period led in the formation of a Neo-Lamarckian school to which most North American vertebrate paleontologists belonged. All the members of this school were enthusiastic supporters of evolution and their contributions furnished an enormous amount of the paleontologic evidence for evolution. But it was this paleontologic evidence consisting of oriented sequences of mammalian phylogenies that prevented their accepting the randomness of Darwinian natural selection as the primary operating force.

A few quotations will, I hope, substantiate my thesis.

In North America Joseph Leidy was the most prominent vertebrate paleontologist in the Darwinian period. The *Origin of species* did not fall on infertile ground; Leidy had already in 1848 expressed earlier a general belief in evolution:

> The study of the earth's crust teaches us that very many species of plants and animals became extinct at successive periods, while other races originated to occupy their places. This probably was the result, in many cases, of a change in exterior conditions incompatible with the life of certain species and favorable to the primitive production of others... There appears to be but trifling steps from the oscillating particles of inorganic matter to a bacterium; from this to a vibrio, thence to a monas, and so gradually up to the highest order of life! The most ancient rocks containing remains of living beings indicate the contemporaneous existence of the more complex as well as the simplest of organic forms; but, nevertheless, life may have been ushered upon the earth, through oceans of the lowest types, long previously to the deposit of the oldest paleozoic rocks as known to us.

It will be seen from this quotation that Leidy certainly had a concept distinctly above that of the "scale of nature." He believed in the extinction of forms, of course, and plainly expresses the germ of evolution, even the development of living matter from nonliving matter.

Leidy, one of the most competent vertebrate paleontologists North America has produced, confined most of his paleontological writing to the description of new types. While he firmly believed in the doctrine of descent, he refrained from theorizing as to the manner in which such descent came about. In many ways this is understandable, since Leidy's period of work coincides with the beginning of the discovery of the vertebrate paleontological treasures of the West. The vast tonnages of specimens and the discovery of the sedimentary sequence of the Tertiary did not come until Marsh and Cope took over the field. At any rate, Leidy did not theorize or speculate in print concerning the Darwinian proposal of natural selection.

Of his two successors Marsh and Cope, the latter became the leader of a group which until quite lately had survivors known as the Neo-Lamarckists. Of the two Cope wrote more extensively and expressed his ideas on natural selection more freely than did Marsh. However, from the few statements on this subject made by Marsh it is quite obvious that he was a member of the same school. In Marsh's vice-presidential address before the American Association for the Advancement of Science meeting at Nashville, Tenn., on August 30, 1877, he says:

> As a cause for many changes of structure in mammals during the Tertiary and Post-Tertiary, I regard as the most potent, *natural selection*, in the broad sense in which that term is now used by American evolutionists. Under this head I include not merely Malthusian struggle for life among the animals themselves, but the equally important contest with the elements and all surrounding Nature. By changes in the environment, migrations are enforced, slowly in some cases, rapidly in others, and with change of locality must come adaption to new conditions, or

extinction. The life history of Tertiary mammals illustrates this principal at every stage, and no other explanation meets the facts.

I think it very likely that Marsh herein referring to "natural selection, in the broad sense in which that term is now used by American evolutionists" is referring to the Neo-Lamarckian school as conceived by Cope, but about this I cannot be certain.

In Marsh's retiring presidential address before the same organization at Saratoga, N. Y., August 28, 1879, Marsh is not even as explicit as he had been the previous year. He states:

> Just 20 years ago, science had reached a point when the belief in "special creations" was determined by well established facts, slowly accumulated. The time was ripe. Many naturalists were working at the problem, convinced the Evolution was the key to the present and the past. But how had Nature brought this change about? While others pondered, Darwin spoke the magic word—"*Natural Selection*," and a new epoch in science began.

A little farther along in the address Marsh continues:

> The publication of Charles Darwin's work on the "Origin of Species," November, 1859, at once aroused attention, and started a revolution which has already in the short space of two decades changed the whole course of scientific thought. The theory of "Natural Selection," or as Spencer has happily termed it, the "Survival of the Fittest," had been worked out independently by Wallace, who justly shares the honor of the discovery. We have seen that the theory of evolution was proposed and advocated by Lamarck, but he was before his time. The anonymous author of the "Vestiges of Creation," which appeared in 1844, advocated a somewhat similar theory which attracted much attention, but the belief that species were immutable was not sensibly affected until Darwin's work appeared.

Beyond Marsh's magnificent contributions to the documentation vertebrate paleontology furnishes to evolution these are the only two short statements in which he appears to give forth his views concerning natural selection. Neither is sufficiently complete to furnish any great light concerning Marsh's view on the mechanics of evolution, and although he does lip service to natural selection the telling remark in the first quote: "natural selection, in the broad sense in which that term is now used by American evolutionists," seems to make him a follower of the Neo-Lamarckists school.

Cope, on the other hand, left absolutely no question concerning his views on the mechanics of evolution. More than 50 titles concerning evolution are cited by Osborn in his biography of Cope. From these it is necessary to choose only one as illustrative of the later concepts of Cope with regard to natural selection. I quote from *The primary factors of organic evolution*, 1896, on p. 474:

> That natural selection cannot be the cause of the origin of new characters, or variation, was asserted by Darwin[1]; and this opinion is supported by the following weighty considerations:
>
> 1. A selection cannot be the cause of those alternatives from which it selects. The alternatives must be presented before the selection can commence.
>
> 2. Since the number of variations possible to organisms is very great, the probability of the admirably adaptive structures which characterized the latter, having arisen by chance, is extremely small.
>
> 3. In order that a variation of structures shall survive, it is necessary that it shall appear simultaneously in two individuals of opposite sex. But if the chance of its appearing in one individual is very small, the chance of its appearing in two individuals is very much smaller. But even this concurrence of chances would not be sufficient to secure its survival, since it would be immediately bred out by the immensely preponderant number of individuals which should not possess the variation.
>
> 4. Finally, the characters which define the organic types, so far as they are disclosed by Paleontology, have commenced as minute buds or rudiments, of no value whatever in the struggle for existence. Natural selection can only effect the survival of characters when they have attained some functional value.
>
> In order to secure the survival of new character, that is, of a new type of organism, it is necessary that the variation should appear in a large number of individuals coincidentally and successively. It is exceedingly probable that this is what has occurred in past geologic ages. We are thus led to look for a *cause* which affects equally many individuals at the same time, and continuously. Such *causes* are found in the *changing physical conditions* that have succeeded each other in the past history of our planet, and the *changes of organic function necessarily produced thereby*. (Italics mine.)

Cope and Marsh were shortly followed by Scott and Osborn as leaders in the field of vertebrate paleontology in the United States. Scott in 1926 in his book entitled *The theory of evolution* (from the Westbook Lectures delivered before the Wagner Free

[1] *Origin of species*, ed. 1872, p. 65.

Institute of Science, Philadelphia) on page 151–152 has this to say:

> Of late years, a host of experiments have been performed upon animals, the larger number of them with the object of determining whether new characters, acquired during the lifetime of the parents, can, under any circumstances, be transmitted to the offspring. This is one of the most hotly disputed questions of modern biology and our whole conception of the efficient factors which have brought about evolution hinges upon the answer to this question. The same experiments are interpreted in diametrically opposite senses by different writers according to their predisposition and general point of view. At the present time, it is probable that a very considerable majority of zoologists and botanists, especially in this country, are inclined to deny the hereditary transmission of characters acquired in the post-embryonic life of the parents, but the problem is still far from definite solution. Important as this problem is in an attempt *to explain* evolution and the manner in which it has been effected, it has no bearing upon the question which I have been endeavoring to answer in these lectures, as to the probable truth of the evolutionary theory. That theory is held quite as strongly by those who affirm the transition of acquired characters. Whatever interpretation be put upon the significance of the experiments, presently to be mentioned, as to the problem of acquired characters, they do, at all events, show that hereditarily transmissible modifications may be artificially produced in both animals and plants.

Scott proceeds in pages following this quotation to enumerate experimental evidence of the inheritance of acquired characteristics as Cope had done before. In Scott's revision of *The history of land mammals in the Western Hemisphere* of 1937 his discussion of evolution is somewhat modified:

> While the theory of evolution is accepted by naturalists with substantial unanimity, there is great divergence of opinion among them concerning the efficient causes of the marvelous transformations which the fossils reveal. Darwin's theory of Natural Selection does offer an explanation, though he himself was far from attributing to that agency the exclusive importance which his modern followers ('Neodarwinians') ascribed to it. He also attached much significance to the direct action of the environment and to the effects of use and disuse and, toward the end of his life, he was inclined to the belief that he had underestimated these factors and overestimated Natural Selection. According to the modern version of Darwin's theory, random variations supplied the material from which Natural Selection picks the favorable ones, just as does the breeder of animals or plants in establishing a new variety. Natural Selection, in Darwin's view, was the exact analogue of the breeders artificial selection.
>
> This is not the place to present the arguments, *pro* and *con*, over this famous theory, which is still upheld by many high authorities, further than to say that, in the writer's opinion the observed facts of parallelism and convergence are fatal to it. The chances than random variations should bring about the astonishing likeness between the marsupial *Thylacosmilus*, the carnivore *Eusmilus*, and the ungulate *Uintatherium*, or the conversion of hoofs into claws in three unrelated groups, are mathematically *nil*. Few paleontologists have felt that the direct, unswerving, step-by-step development of the ammonites studied by von Waagen and Neumayr, or of the many mammalian series, which have been described in the preceding chapters, were satisfactorily accounted for by Natural Selection. In giving up this theory, it must be admitted, there is nothing to put in its place. Darwin's theory does offer an explanation of the evolutionary process and this no other theory does, but the question remains: is it an adequate explanation?

The answer to Scott's question so far as the vertebrate paleontologists were concerned was no. It was certainly inadequate for Osborn because he proposed a further alternative, aristogenesis, which was vitalist in its essential form although Osborn denied this.

Vertebrate paleontology is an observational and descriptive science, and the North American workers were busily observing and describing the spectacular material discovered with the opening of the West. Genetics, an experimental science, was born a little later, and during the 1920's and 1930's its workers were busily acquiring experimental proof of the mechanics of evolution. During this period of the marshaling of the evidence in both fields the chasm between them grew.

The turning point when the chasm began to narrow goes back, in my opinion, only to the publication of J. Huxley's *Evolution: The modern synthesis* in 1942. The chasm closed, so far as vertebrate paleontologists are concerned (with some exceptions) only in 1944 with the publication of G. G. Simpson's *Tempo and mode in evolution*. Within the synthesis Darwinian natural selection has been modified somewhat. With this modification both the oriented and random aspects of evolution are satisfactorily explainable, at least for the present.

Impact of the Development of Photogrammetry upon Geology

By David Landen, *U. S. Geological Survey*

The modern specialized scientist, immersed in the particular problems of his own field, needs to raise his head at opportune times and see what is going on in other fields. What he sees when he looks about is a vast complex of progress in many scientific disciplines. This progress offers both a challenge and an opportunity. The scientist can often save himself costly and tedious work by discovering the useful tools scientists have already developed in other fields and adapting them to his special purposes.

In the marriage of the disciplines of photogrammetry and geology, we have an excellent illustration of this point. Scientists, operating in the specialized field of geology, have recognized the challenge of photogrammetry and have seized the opportunity to espouse it. The linking of photogrammetry, the science of making reliable measurements by means of photographs, to the science of geology was for many years a slow process; only in the last decade has it experienced a rapid acceleration.

EARLY USE OF PHOTOGRAPHY FOR RECORDING SCIENTIFIC DATA

As far back as 1853, a famous scientific expedition, under the leadership of Col. John C. Frémont, employed a photographer to obtain reliable records of geologic and geographic features encountered on a route of exploration. This expedition set out from Westport, Mo., with the objective of crossing the Rocky Mountains near the thirty-eighth parallel, in quest of a direct route to California. A key member of Frémont's party was Solomon N. Carvalho,[1] a daguerreotypist and artist from Baltimore, who was the first official photographer to accompany a Western expedition. In his account of the journey, *Incidents of travel and adventure in the Far West* (New York, 1858), Carvalho describes the intricate process of mixing chemicals and preparing daguerreotype plates while standing waist deep in snow with the thermometer registering 20° below zero.

Between 1854 and 1860 at least four more exploration parties employed photographers, with varying degrees of success. The outbreak of the Civil War halted expeditionary photography for the duration. Following the cessation of Civil War hostilities, several separate Government-organized geological-survey expeditions were created to further knowledge concerning national resources in the West. The most important of these were the Hayden, King, Wheeler, and Powell surveys; each of these parties included a photographer. The photographic work of these survey expeditions was considerably more successful than that of the earlier expeditions, owing largely to three factors: the superiority of the wet-plate process over the daguerreotype process, the availability of commercially prepared collodion, and the experience acquired by the photographers during the Civil War years. An important product of these surveys, made between 1865 and 1880, was the large amount of accurate geologic and geographic data collected, which were represented largely in the form of maps, with photographs serving to illustrate geologic features in detail. Robert Taft gives a list of photographers of this period.[2]

The growing recognition of the value of photography in recording scientific data such as that gathered by the early western surveys led to the formation, in 1890, of a Committee on Photographs of the Geological Society of America. In the first report of this committee[3] we see the first known reference to a new activity: photogeology. The object of the new movement, according to the committee report, was "to make a photo-geologic survey, and to secure for the

[1] Wallace, E. S., *The great reconnaissance:* 126–137. Little, Brown & Co., 1955.

[2] Taft, Robert, *Photography and the American scene:* 308. 1938.

[3] Geol. Soc. Amer. Bull. **2:** 616–6–30. 1890.

Society a national collection of photographs illustrating the geology of the country." The stated uses for such a collection were "first, to furnish to teachers better illustrations in teaching geology, and second, to furnish to investigators material for comparative study."

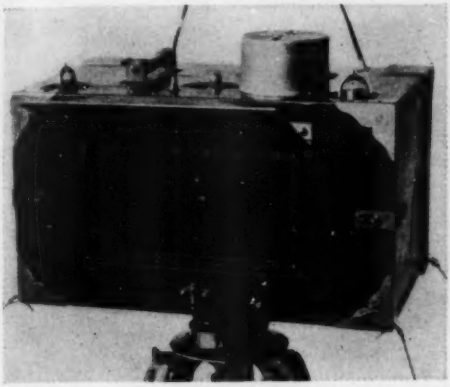


FIG. 1.—Panoramic camera. The first panoramic camera used by the Geological Survey was constructed by C. W. Wright and F. E. Wright in 1904. Later, beginning in 1910, J. W. Bagley improved this camera and extended its use in a program for producing topographic maps.

PHOTOTOPOGRAPHIC SURVEYS

To understand properly the intensive mapping activities by field parties interested primarily in geology, it is important to realize that mapping was considered to be a means to an end. The object was to facilitate the understanding of geology; maps were needed as a base on which geologic data could be plotted.

In 1904, two members of the U. S. Geological Survey staff, C. W. Wright and F. E. Wright,[4] pioneered the use of photogrammetric methods for the development of topographic maps needed specifically as a base for geologic studies. The Wrights, operating in an area of Alaska completely devoid of maps, devised a spring-driven, revolving, panoramic camera (Fig. 1) which afforded a very large field of view. Level bubbles and scales fitted to the camera provided a basis for photogrammetric measurements. Beginning in 1910, James W. Bagley, a topographic engineer of the Geological Survey, developed and improved the panoramic camera with the object of extending its use to the Survey's regular program of producing general-purpose topographic maps. Bagley also designed a panoramic photoalidade (Fig. 2) which enabled the operator to use the photograph for the determination of directions and elevation differences in the same manner in which a topographer operates the telescopic alidade on a plane table in the field. This afforded a basis for drawing planimetry and contours in the construction of a map.

Meanwhile, the use of photographs for mapping had been stimulated by two important advances: (1) the discovery in 1892 by F. Stolze,[5] in Germany, of the principle of the stereoscopic floating mark, and its practical development later, and (2) the advent of the airplane. The floating mark principle offered a satisfactory method of making measurements in the three-dimensional "model" observed when overlapping photographs are viewed stereoscopically. The airplane offered an excellent platform on which a camera could be moved rapidly from exposure station to exposure station; furthermore, aerial photography offered a practical means of obtaining a vertical view of the terrain, with its inherent superiority over terrestrial photography, for mapping purposes. These events opened the way to the widespread use of aerial photographs in stereoscopic plotting equipment; maps could now be produced by continuous plotting instead of the old tedious point-by-point methods. The two advances also accelerated the development of a large number of accurate stereoscopic plotting instruments for mapping. Eventually, it was found that, in general, maps of comparable accuracy could be obtained at lower costs with the new aerophotogrammetric techniques than with the older ground methods.

In 1916, after studying the work of Scheimpflug, the Austrian inventor of a multiple-lens camera, Bagley and another mem-

[4] LANDEN, DAVID, *History of photogrammetry in the United States*. Photogrammetric Eng. **18**(5): 857. December 1952.

[5] VON GRUBER, O., *Photogrammetry:* 163. American Photographic Publishing Co., Boston, 1932.

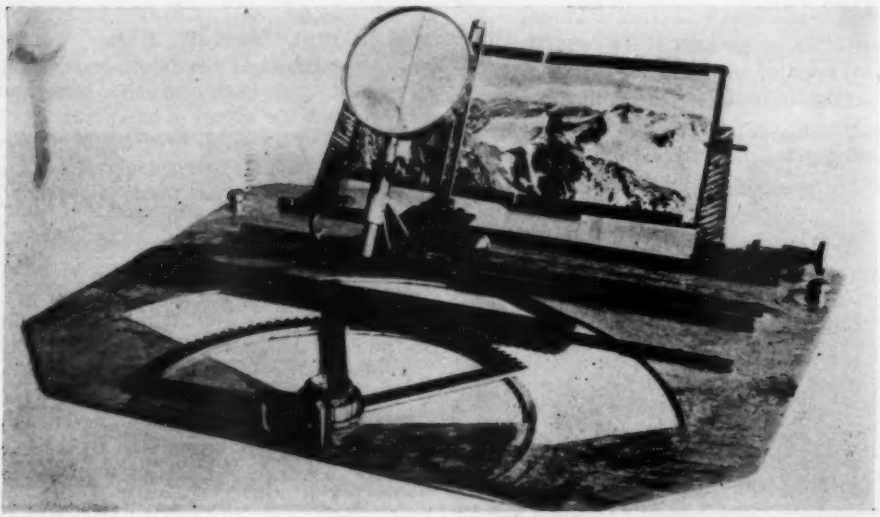


FIG. 2.—Panoramic photoalidade.

ber of the Geological Survey, J. B. Mertie, undertook the task of developing a tri-lens camera (Fig. 3). Meanwhile, another colleague, F. H. Moffit, designed a transforming printer (Fig. 4) as a companion piece to the camera. After Bagley was commissioned a major in the Engineer Reserve Corps, in 1917, he continued his interest in phototopographic mapping. The first aerial photographs taken with the tri-lens camera were made at Langley Field in 1917–1918 with the cooperation of the Air Service. This event marks the actual beginning of aerial surveying in the United States; the tests led to a program of producing aeronautical charts of the terrain between flying fields. Multiple-lens cameras are in use for obtaining mapping photography to this day, notably the nine-lens camera of the U. S. Coast and Geodetic Survey which has been in use since 1936. For the great majority of modern photogrammetric mapping projects,

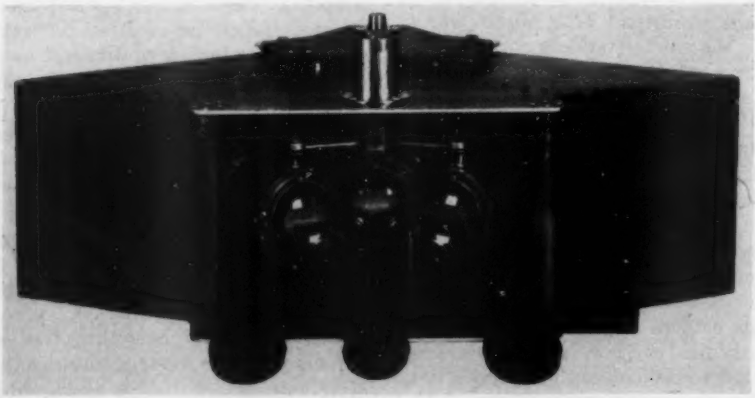


FIG. 3.—Tri-lens camera. Designed in 1916–17 by J. W. Bagley, with the assistance of J. B. Mertie and F. H. Moffit, and developed by the Corps of Engineers, U. S. Army. Later, cameras of this general design were built with 4- and 5-lens combinations.

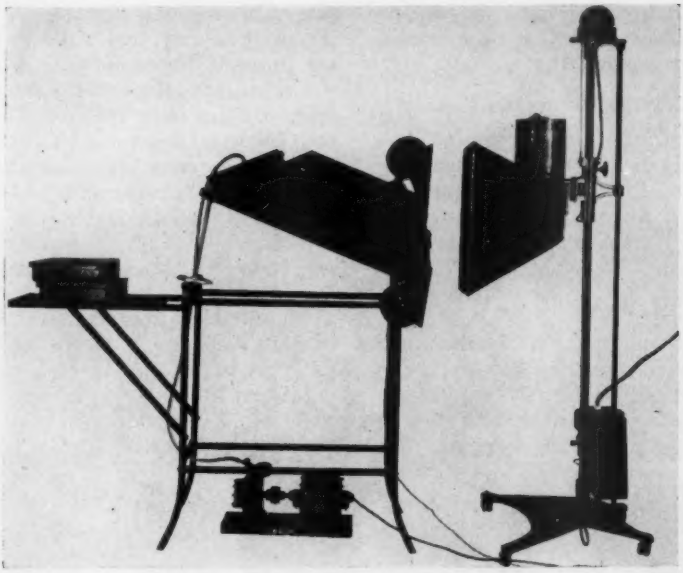


FIG. 4.—Transforming printer. Designed by F. H. Moffit in 1916–17, this transforming printing-camera was used to project the side negatives of the tri-lens camera so as to bring the photographs to the same plane and scale of the center photograph.

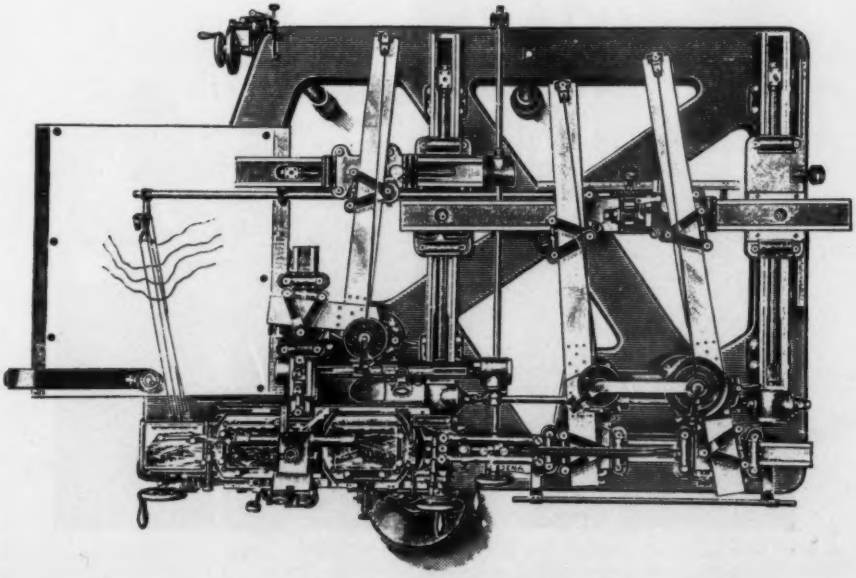


FIG. 5.—Plan view of the stereoautograph.

however, aerial photography is obtained with a single-lens camera or a combination of single-lens cameras.

AMERICAN USE OF STEREOSCOPIC MAPPING INSTRUMENTS

In the early 1920's the Brock and Weymouth Co. of Philadelphia designed and built the first American stereoscopic plotting equipment, and in 1923 they compiled the first topographic map produced commercially on such a machine in the United States.

Meanwhile, in 1921, a semiautomatic plotting machine, the stereoautograph (Fig. 5), was received (on loan) from Germany for testing by the Geological Survey's newly established Section of Photographic Mapping. This instrument employed terrestrial photographs only, and while workable, did not prove to be economical. A second instrument, the Hugershoff aerocartograph (Fig. 6), was imported from Germany by the Geological Survey in 1927; this was the first precise stereoscopic plotting instrument utilizing aerial photography to be owned by the United States Government.

Although the aerocartograph produced satisfactory contour maps, its initial cost was high and it was mechanically complex. The multiplex aeroprojector, manufactured by Zeiss in Germany, overcame these disadvantages, and in 1935 the Geological Survey purchased its first multiplex equipment. (See Fig. 7, Principle of multiplex.) Once the value of the multiplex was demon-

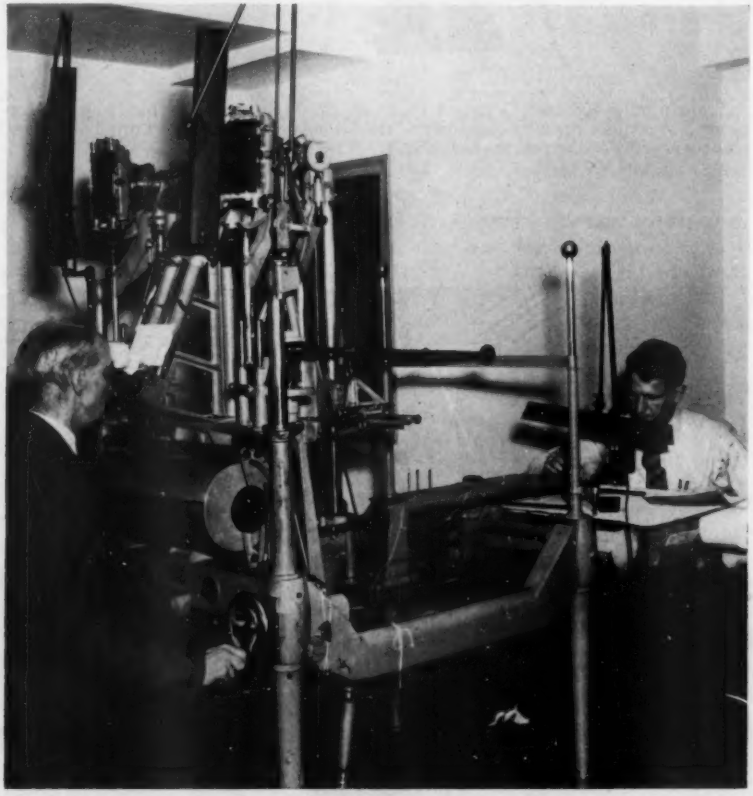


FIG. 6.—The Hugershoff aerocartograph. The (German) aerocartograph is a complex stereoplotting instrument using the optical-mechanical projection principle. While it is capable of producing good maps from either vertical or terrestrial photographs, its use, together with narrow-angle photographs is now considered obsolete, as it was replaced by more modern wide-angle plotting instruments.

strated, it was put into widespread use, first in topographic mapping in the Tennessee River Valley, then in the topographic mapping of other areas throughout the country. During World War II this equipment was used in carrying out formidable strategic mapping assignments of high importance.

Following World War II, two important new plotting instruments were developed by the Geological Survey: the Kelsh plotter (Fig. 8) and the ER-55 plotter (Fig. 9). Both of these instruments embody the general principle of the multiplex but have features which result in greatly superior per-

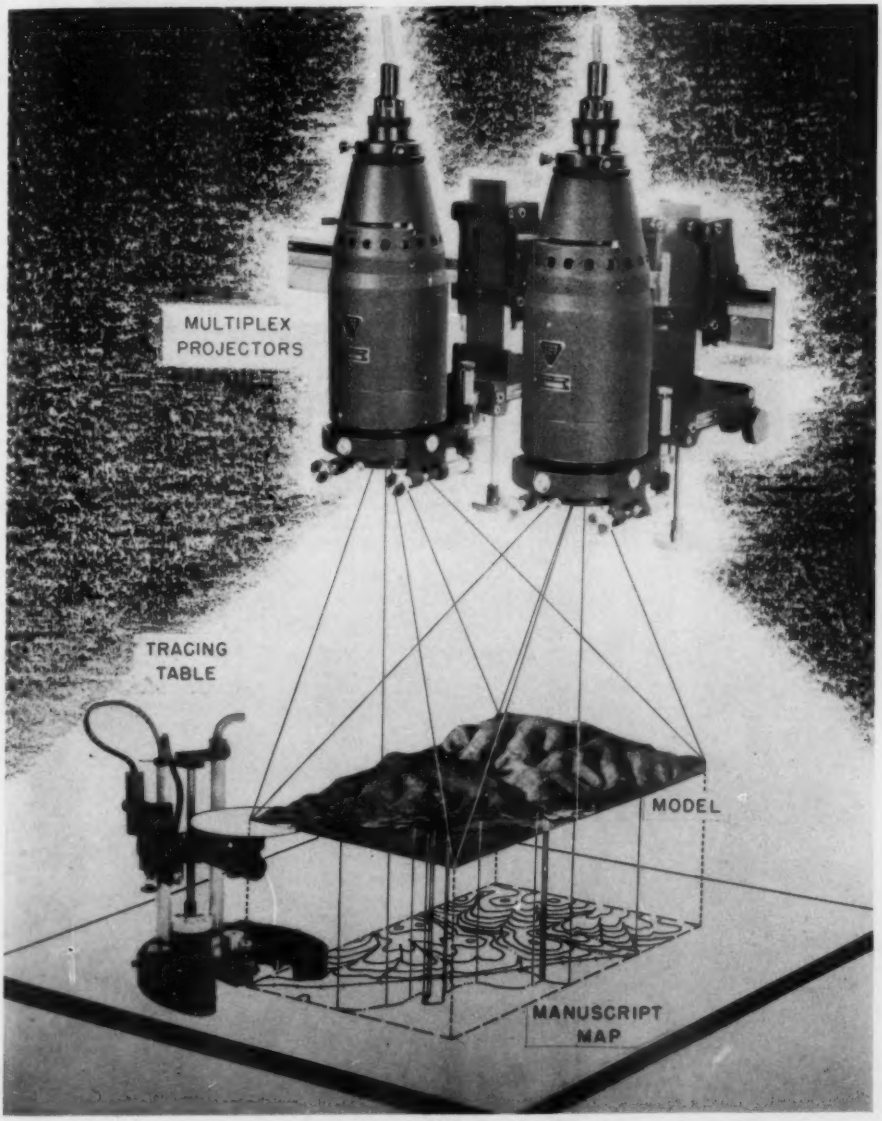


FIG. 7.—Principle of multiplex.

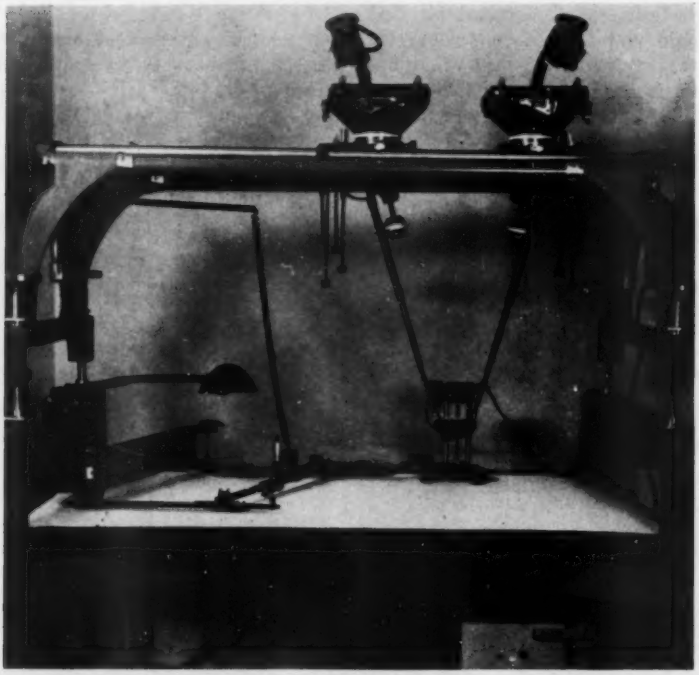


FIG. 8.—Kelsh plotter. Conceived by H. T. Kelsh in 1943, the Kelsh plotter was developed by him in 1947 and later by members of the Geological Survey technical staff. The main advantages of this plotter over previous double-projection plotters are the swinging light source; correction, when necessary, of camera lens distortion by means of an arm-and-cam arrangement; and contact (negative) size diapositive plates.

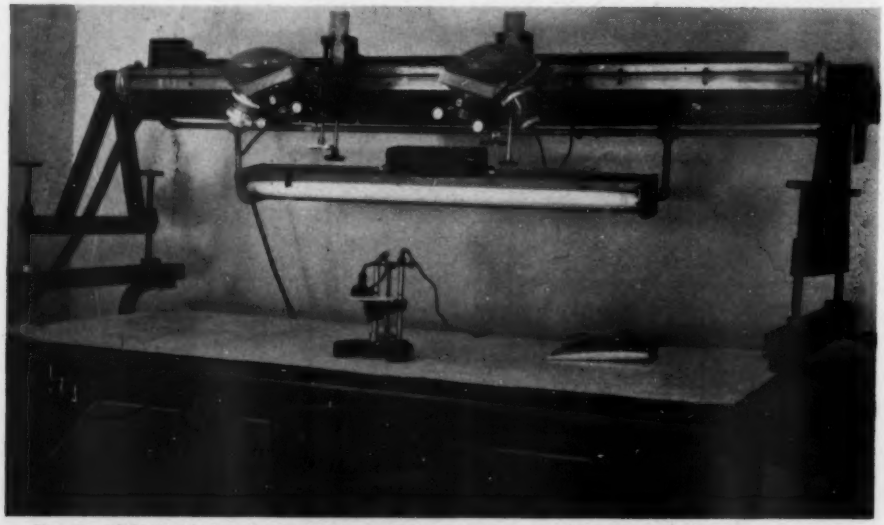


FIG. 9.—ER-55 plotter. Two ER-55 optical projectors are shown mounted on a standard multiplex supporting frame. The projectors are arranged for convergent photography.

formance. Commercial versions of these two instruments are now the leading American-made instruments of this type on the American market.

In addition to the American-made instruments, numerous foreign-made instruments are to be found in use for high-precision topographic mapping in this country. (See Fig. 10, Wild plotter.) Among these are numerous instruments made by Zeiss Aerotopograph (Germany), Henry Wild (Switzerland), Officine Galileo (Italy), and Ottica Mecanica Italiana (Italy). Despite their complexity and high first cost, these instruments find an important use because of their versatility and increased capability.

RATE OF PROGRESS OF THE UNITED STATES MAPPING PROGRAM

In view of the need for good topographic maps on which to plot geologic data, the rate of progress of the United States mapping program is of vital importance to the geologic profession. The lack of a suitable map of the area of interest can delay a geologist's operations by weeks or months.

Fortunately, Congress has recognized the vital importance of the national topographic mapping program and has, in recent years, appropriated the funds needed to permit an increase of several times in the annual map output as compared to that of a decade ago. At the current rate, about 100,000 square miles of U.S.G.S. quadrangle maps at the scales of 1:24,000 and 1:62,500, are completed annually.

As of 1958, the Geological Survey distributes some 20,000 separate topographic maps produced by Federal agencies. These maps are published at various scales ranging from 1:24,000 to 1:250,000 (see Fig. 11, Status of topographic mapping).

FIG. 10.—Wild autograph A-7 (Swiss). The autograph is a complete stereoplotting instrument of the mechanical projection class. The instrument can be used for control extension by aerotriangulation as well as for map compilation. Despite the initial high cost and complexity, its versatility and high order of accuracy make it suitable for a wide range of special projects, with long-range economies in operation.

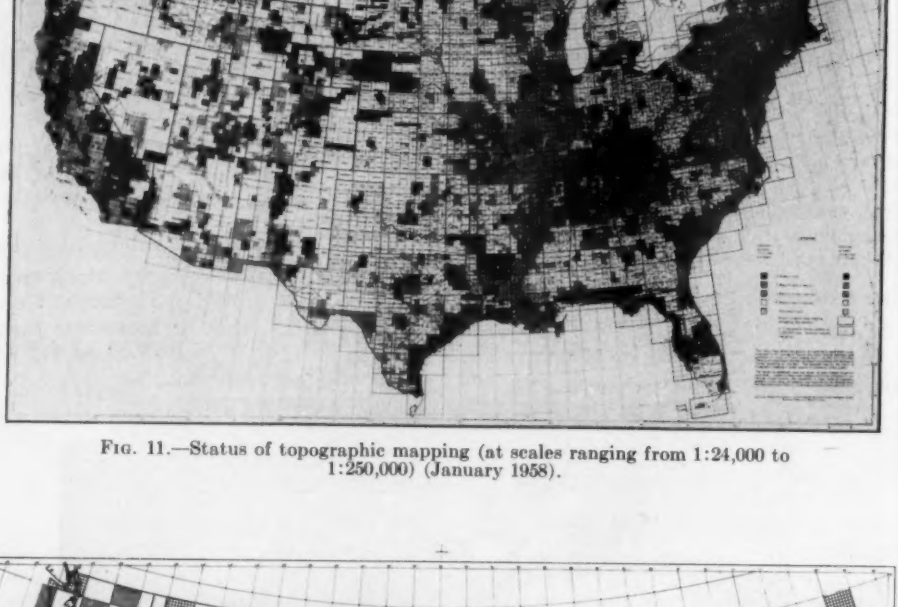


FIG. 11.—Status of topographic mapping (at scales ranging from 1:24,000 to 1:250,000) (January 1958).

INDEX TO TOPOGRAPHIC MAPS OF THE
UNITED STATES
PUBLISHED AT THE SCALE OF 1:250 000
NOVEMBER 1958
PUBLISHED
BLACK AND WHITE ADVANCE PRINT OF UNEDITED BASE COMPILATION 1:250,000 SCALE, AVAILABLE AT $3.50. (SHOWS CULTURE, DRAINAGE, AND CONTOURS, BUT NO NAMES)

FIG. 12.—Index to topographic maps of the United States, published at the scale of 1:250,000 (November 1958).

Quadrangle maps at a scale of 1:250,000 are also available, in a preliminary series, for the entire State of Alaska. In addition, more detailed mapping of a type that may be termed "adequate" is already available for about 29 percent of Alaska's tremendous land area. When Arizona, the last State to be admitted previously, entered upon statehood in 1912, only 1 percent of its area was adequately mapped.

The new series of 1:250,000-scale topographic maps of the United States, originally prepared by the Army Map Service, but now being published in civilian editions by the Geological Survey, is of particular interest because it provides nearly complete coverage of the country. (See Fig. 12, Index to 1:250,000-scale maps.) In addition to the 1:250,000-scale maps themselves, geologists have access to the rather recent high-altitude aerial photography and other source materials used in preparing the maps. These materials, obtainable from the Geological Survey, may provide detailed information in areas of interest not covered by larger-scale quadrangle maps. Much of this topographic mapping is a result of the use of high-altitude aerial photography flown at heights as high as 36,000 feet.

PHOTOGRAMMETRY AND ACCURACY STANDARDS

Not only does photogrammetry provide a means of increasing the rate of topographic mapping but it also provides the means whereby accuracy standards can be established on a practical basis for maps of all types of terrain.

The practical value of geologic information, however well catalogued, may be seriously limited if the location of the items described is not accurately known. It is therefore quite important to the geologist that he recognize the characteristics of the topographic map on which geologic data is to be plotted, with respect to the accuracy of the positions and elevations of features shown on the map.

The idea of producing topographic maps conforming with specified standards of accuracy has long been known, and indeed many maps meeting rigid specifications have been prepared over the years, by classical methods, where such procedure was economically justified. It was not until the advent of photogrammetric techniques and parallel advances in related field-survey procedures, however, that attainment of standard accuracy in nearly all of the quadrangles of the National Topographic Map series became economically feasible. Since the early 1940's, most topographic maps produced by or for the Federal mapping agencies have been prepared to comply with standard specifications for horizontal and vertical accuracy. Maps made in accordance with these specifications are so designated by the following statement printed on the bottom of the sheet: "This map complies with National Map Accuracy Standards." This statement assures the geologists, forester, engineer, or other user that the map has been made under carefully controlled conditions and that the information given can be relied on within the provisions of the accuracy specifications.

SPECIAL-PURPOSE MAPS

The general-purpose topographic maps produced by the Federal agencies cannot be expected to meet all the specialized requirements of all the map users with respect to scale, contour interval and map content. To meet such requirements, photogrammetry offers a valuable means for producing special-purpose maps at relatively low cost.

Several government agencies, having specialized map requirements for studies in geology, forestry, agriculture and other fields, maintain their own photogrammetric facilities for producing the needed special-purpose maps. Likewise, a number of commercial organizations, such as oil companies, operate photogrammetric installations for producing needed geologic and other scientific data.

The organization or individual that needs special-purpose maps but is not in a position to operate photogrammetric facilities may wish to consider the services of the various commercial firms that are equipped to perform such tasks. Firms of this type are to be found in all parts of the United States; in general, they operate their own photographic aircraft and photogrammetric plotting equipment.

SOME EXAMPLES OF SPECIAL-PURPOSE MAPPING

Some representative examples of the use of photogrammetric techniques in geology are shown by the following illustrations:

a. A structure contour map (Fig. 13)

b. An isopachous map (Fig. 14)

c. A compilation of photogeology and surface geology is shown in Fig. 15—a photogeologic map of the Notom-15 quadrangle, Garfield County, Utah. The only available control information was outside the area mapped, and all the photogeologic data was derived from photographs. The structure contours shown are based on measurements obtained with a multiplex plotter.

Two additional examples of large-scale special-purpose mapping further illustrate the use of photogrammetry for the solution of scientific and engineering problems:

d. A beach-erosion study (Fig. 16). A large-scale map of a heavily eroded beach at Gay Head, Massachusetts, was compiled from aerial photographs flown at 1,500 feet above ground. The scale of the required map was 1:600 (50 feet to the inch). Two-foot contours were plotted with the Kelsh plotter. It is planned to remap the area chronologically on a yearly basis to record the rate of erosion and its relation to the topography and resistance of surficial materials.

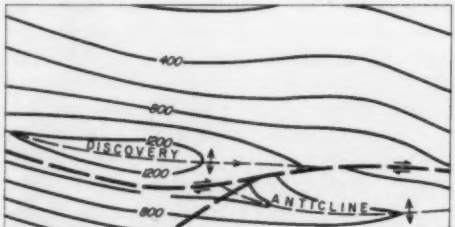


FIG. 13.—Portion of a structure contour map. This figure shows an enlarged portion of a structure contour map of Discovery Anticline in northern Alaska (U. S. Geol. Surv. Spec. Rep. 42, pl. 1, 1:40,000 scale). Measurements that were used to develop the structure contours were made from aerial photographs with a stereometer. (A structure contour is a contour line drawn through points of equal elevation on a stratum, key bed, or horizon, in order to depict the attitude of the rocks.) The contour interval is 200 feet, and the reference datum is approximately sea level.

FIG. 14.—Example of isopachous map. Portion of an area in Monument Valley, northeastern Arizona, showing isopach intervals of 10 feet. (Isopachous line are contour lines which show the thickness of a formation.) A Kelsh plotter was used to measure the thickness of the formation and to plot the location of these measurements on a base map.

e. Photogrammetric mapping of sand beds in a hydraulic test flume[6] (Fig. 17). In connection with a wide range of studies of phenomena relating to the problems of water shortages and soil erosion, an unusually large-scale map was made of sand dune configurations, resulting from flowing water in a hydraulic test flume. Contour maps (Fig. 18) were prepared at 1:2 scale (half-size) with a contour interval of 0.01 foot, from photographs taken at a height of 65 inches (5.4 feet). A Wild A-8 plotter was employed. The cyclical recurrence of ridges and depressions in the sand dune pattern is plainly evident. Wavelengths and amplitudes of the configuration can be easily determined. This map was tested and was found to comply with standard-accuracy specifications.

SOME EXAMPLES OF PAPER-PRINT PLOTTERS

Many of the less-exacting tasks required in the plotting of data compiled on or from photographs can be performed with less

[6] THOMPSON, M. M., *Photogrammetric mapping of sand beds.* Photogrammetric Eng. **24**(3): 468–475. June 1958.

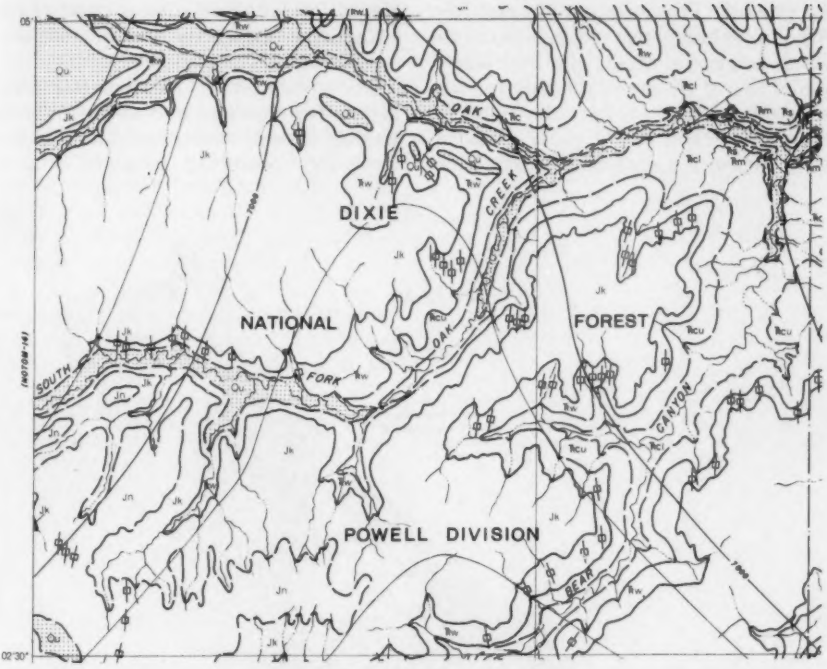


FIG. 15.—A compilation of photogeology and surface geology. Portion of Notom-15 quadrangle, Garfield County, Utah.

costly and less complicated instruments than those required for high-precision topographic mapping. These instruments are generally characterized as "paper-print plotters," as contrasted with the precision mapping plotters which invariably use glass-plate diapositives (positive photographs printed on glass instead of on paper). Among the more popular paper-print stereoscopic plotters are the Kail radial planimetric plotter, the K.E.K. Plotter, and the Ryker-Wernstedt-Mahan plotter. (See Fig. 19, K.E.K. plotter.)

Another simple instrument, the sketchmaster, based on the camera lucida principle, permits the transfer of detail from the photograph to the map. (See Fig. 20, Vertical sketchmaster.)

Until recently, the paper-print plotters constituted the prevailing type of instrument for use in photo-geologic operations. Lately, however, there has been an increasing use by geologists of modern precision stereoplotting instruments, such as the Kelsh plotter, for making quantitative measurements, for transferring geologic data from the photographs to the map, and for photointerpretation.

SOME EXAMPLES OF SPECIAL-PURPOSE PHOTOGRAMMETRIC INSTRUMENTS FOR MAKING QUANTITATIVE MEASUREMENTS

In addition to providing a variety of general-purpose and special-purpose maps, photogrammetry has already provided a large number of special instruments for making quantitative measurements that are useful in scientific studies. Geologic mapping, for example, employs basic measurements such as distance, elevation, or direction, as intermediate steps in the solution of some larger problem. Some of the instruments described herein can be used to obtain measurements such as dips, strikes, thickness of beds, profile elements and the like; measurements heretofore largely made

on the ground. The forester, for example, can use photogrammetric measurements for obtaining heights of trees; the hydrologist can make use of these instruments for watershed and gradient studies; the engineer, for example, makes use of these measurements in highway design and construction, etc. A few of these special-purpose photogrammetric measuring instruments are described below:

The parallax-bar, or stereometer (Fig. 21) is both the oldest as well as the most simple photogrammetric instrument available. It is used for measuring parallax differences.

FIG. 16.—Large-scale map for beach erosion study, Gay Head, Mass. Scale 1:600; contour interval 2 feet. Made with Kelsh plotter.

(The parallax of an object is its apparent displacement due to its being viewed from two different viewpoints.) By measuring the horizontal separation between individual dots placed at the bottom of an object to be measured, then measuring the separation, or parallax, at the top of the object, the difference between the two parallax readings can be directly related to the height of the object. With the stereometer shown parallax can be measured to hundredths of a millimeter.

The photogrammetric dip angle indicator (Fig. 22) is a device for making direct measurement of dip, or angle of slope, in the

FIG. 17.—Photogrammetric mapping of sand beds in a hydraulic test flume. (The white spots are heads of tacks used as vertical accuracy test points.)

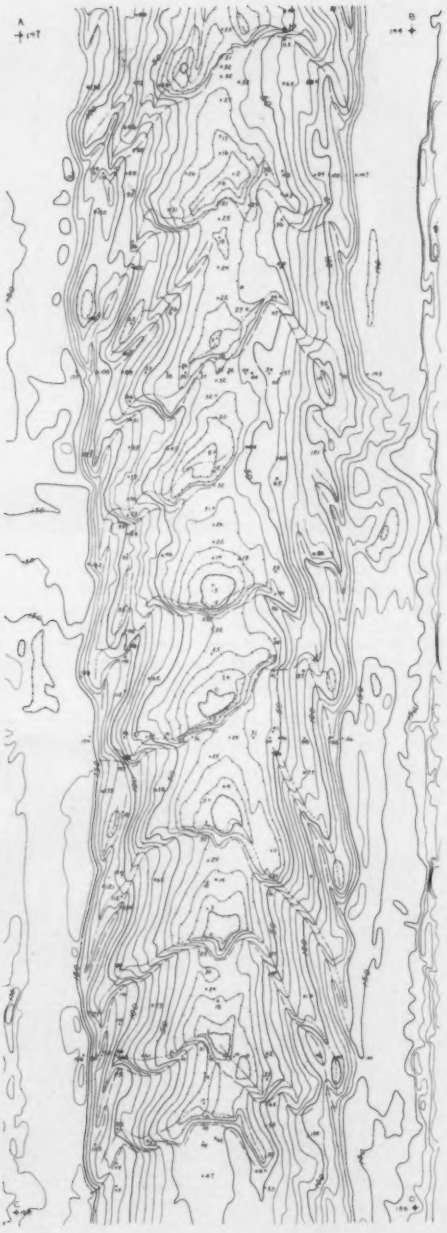


FIG. 18.—Contour map of sand beds compiled on Wild A-8. Contour interval, 0.01 foot.

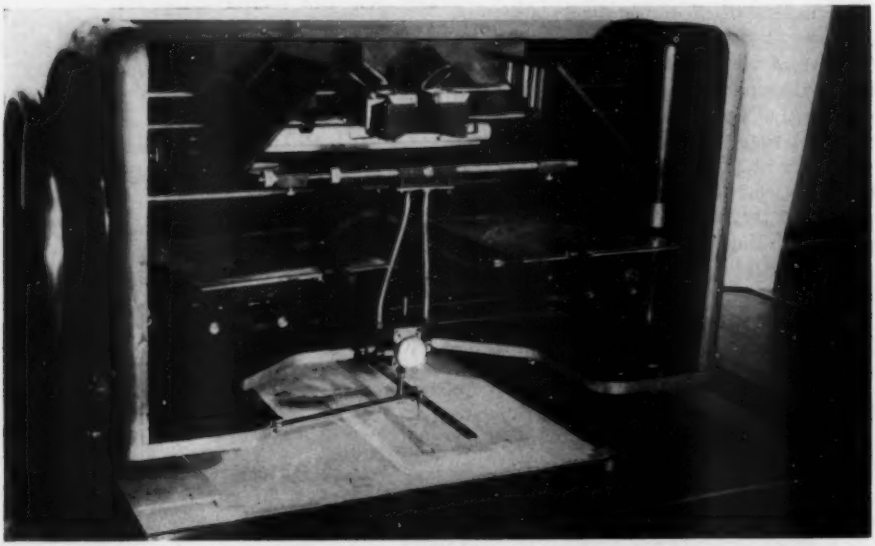


FIG. 19.—KEK (Kail, Elliot, King) plotter. The KEK plotter consists of a stereoscope for viewing a pair of photographs mounted upon two tables, a pair of floating marks scribed on glass disks, and a plotting device attached to a pantograph. By raising or lowering the plate-carriers the floating mark is placed in contact with the ground in the stereoscopic model so that planimetric detail can be plotted on the map. Elevations are read on a drum scale linked to the plate-carriers. The floating mark can be set to any desired contour interval and permits contouring when the photographs are well controlled. Since the instrument is based on certain approximations and does not produce a geometrically true model, it is not intended for precision work.

FIG. 20.—Vertical sketchmaster. This portable instrument based on the camera-lucida principle was designed by J. L. Buckmaster of the U. S. Geological Survey in 1931. By means of a mirror arrangement, the sketchmaster permits the photograph and the plotting sheet to be viewed simultaneously, thus making possible the transfer of detail from the vertical photograph to the plotting sheet. Adjustments are provided for scale changes and approximate tilt correction.

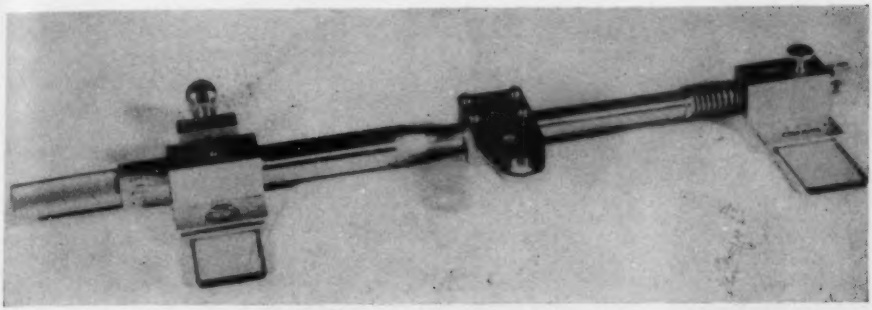


FIG. 21.—The parallax-bar, or stereometer.

stereoscopic model of a double projection plotter. The surface of the platen shown is gridded with suitable stereoscopic floating marks. A vertical angle arc, passing through a slot in the platen, is used for making direct measurements of angles of slope. A strike line can be plotted graphically, at right angles to the plotted direction of dip.

A photogrammetric profile plotter[7] (Fig. 23) is an instrument for plotting profiles directly from multiplex-type stereoplotting equipment. Profiles are often used, in combination with geologic data, to show geographically the inclination, structural relations and thickness of rock units at the surface or subsurface of the ground. The profile plotter plots the profile directly upon a sheet of graph paper mounted in a vertical plane.

ORTHOGRAPHICALLY RESTITUTED AERIAL PHOTOGRAPHS

One of the important problems of the geologist working with aerial photographs is how to relate, or transfer, information from the photograph which is in a perspective form, to a map which is in an orthographic, or plan, projection.

A new photographic material that has aroused much interest is the orthographically restituted aerial photograph. This new photographic material is called an orthophotograph and the photogrammetric machine which produces it is called an orthophotoscope.[8]

The orthophotoscope (Fig. 24) employs the anaglyphic principle to form a stereoscopic model under a double-projection stereoplotter. The model is mechanically scanned in contiguous strips by a moving aperture which is controlled by an operator to rise and fall while in stereoscopic contact with the terrain being viewed. Photographic detail, located by the intersection of homologous optical rays in true orthographic position, is rephotographed upon a new sheet of film placed directly under the moving aperture and rising and falling with it. The film is sensitive only to the blue light of the red and blue rays forming the anaglyph. After the scanning is complete, the film is removed and orthographic paper prints are made (Fig. 25).

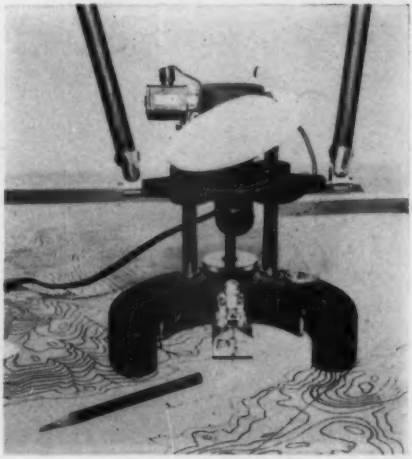


FIG. 22.—Photogrammetric dip (or slope) indicator.

[7] LANDEN, D., *A photogrammetric profile plotter for geologic use*. Photogrammetric Eng. **22**(5): 953–956. December 1956.

[8] SOUTHARD, R. B., *Orthophotography*. Photogrammetric Eng., June 1958.

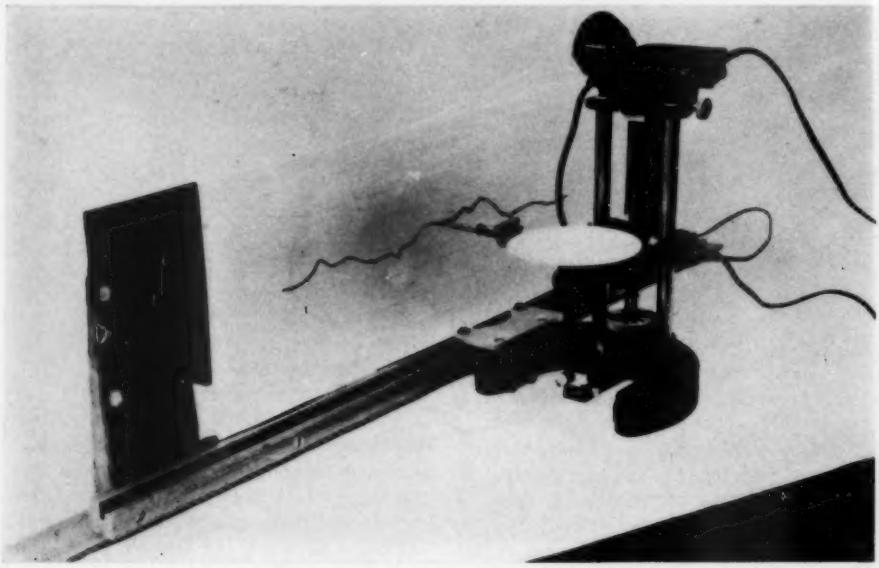


FIG. 23.—Photogrammetric profile plotter.

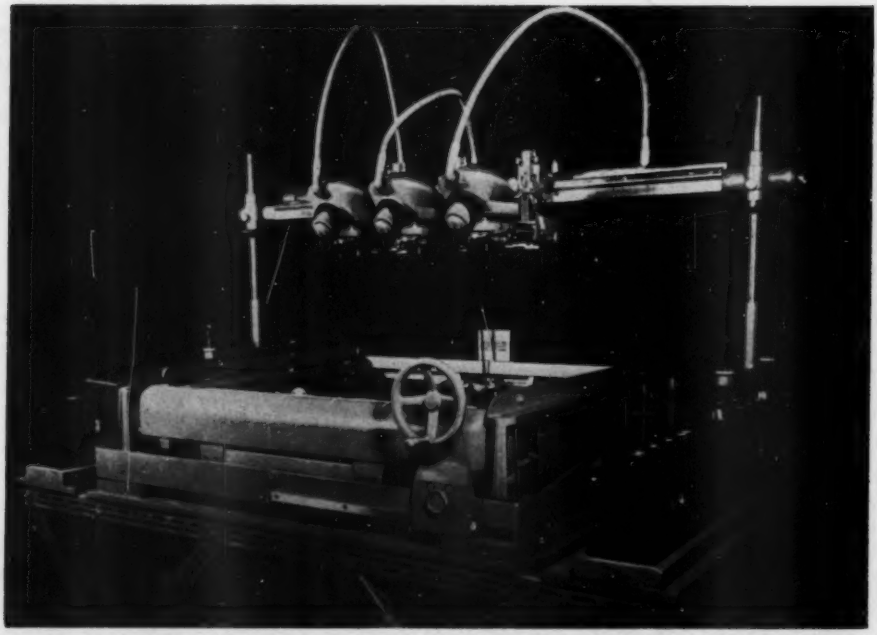


FIG. 24.—1956 model orthophotoscope with ER-55 projectors. The orthophotoscope, developed in the research laboratory of the Geological Survey, under the direction of R. K. Bean, is an apparatus for converting perspective photographs to the equivalent of orthographic photographs.

FIG. 25.—Corresponding portions of a perspective photograph (left) and an orthophotograph (right). In the perspective photograph the powerline appears to be crooked, while in the orthophotograph it is shown in its true, straight alignment.

Experience with orthophotographs by geologists shows that the photographic detail is uniformly in position within nominal accepted tolerances. The orthophotograph facilitates the transferring of geologic details from photograph to map. This can now be done in a simple fashion by tracing; or, the orthophotograph itself can be used as a map.

A somewhat related photographic product is called the photo-contour map.[9] This product provides a topographic map whereon elevations are shown by contours, while planimetry is shown by photographic detail.

[9] MAHAN, R. O., *The photo-contour map.* Photogrammetric Eng. **24**(3): 451–457. 1958.

CONCLUSION

We have seen how photographs and photogrammetry, over a period of a hundred years, have made and continue to make a profound impact on the science of geology. This development has improved the work of the geologist, through its effect in two fields. One was an indirect effect, that of improving the availability, quality, and variety of photo-topographic maps. The other was a direct effect, that of making available in photographic form, a vast amount of quantitative and interpretative data relating to the earth's surface. Geologists have been alert to the possibilities of applying this sister science to the solution of their own problems.

Development of Geologic Thought Concerning Ulster County, New York

BY JULES FRIEDMAN, *U. S. Geological Survey*

In the history of American geology, certain areas have been outstanding in the role they have played in the development of geologic thought. Such an area is Ulster County, N. Y., situated west of the Hudson River and halfway between the igneous and metamorphic highlands of the Hudson and the limestone Helderberg escarpment of the Capitol District. Although more widely known for the geology of its Catskill Mountains, the county also includes part of the Shawangunk Mountains and the Rondout and Wallkill Valleys.

The geomorphic setting of the area, known three centuries ago as the Esopus territory, has exposed it to geologic speculation since the earliest colonial days. By the late nineteenth century, geologic thinking in America was concerned with several stratigraphic problems—the real boundaries of the Ordovician, Silurian, and Devonian systems—for which rock exposures in Ulster County provided many of the problems and some of the solutions. After several mid-nineteenth century developments in mining and quarrying, technological advances opened the way, though inadvertently, for stratigraphic and structural field investigation. During the present century, the area has served as a training ground in Paleozoic stratigraphy for hundreds of American geologists.

Settlement of the Esopus territory of the seventeenth century was controlled largely by geographic factors. The fertile Rondout and Wallkill Valleys, colonized and farmed by the Huguenot French and Dutch, had been occupied by Minsi and Delaware Indians in earlier times. That these Algonkian Indians were as least as aware of their geologic environment as the first European settlers is suggested by their recognition and use of Pleistocene glacial deposits of the Rondout Valley for military strongpoints and for burial grounds, by scores of Indian place names derived from and incorporating rock and landform names, and by their recognition of landforms and drainage in the alignment of their trails. The original inhabitants may also have discovered the

sphalerite-galena ore bodies emplaced in the Shawangunk conglomerate. William Mather, in 1843, wrote, "There are traditions that lead ore has been cut out of Shawangunk Mountain in many places by the Indians and hunters of former days with their hatchets, and melted to make their bullets. Traditions of this kind," continued Mather, "are said to have led to the discovery of the lead ores at Ellenville."

Settlement of the old Indian lands and rapid growth of the sparse population occupied several decades after the American Revolution, and then, in 1828, the Delaware and Hudson Canal was completed between the newly opened anthracite mines near Honesdale, Pa., and Kingston, on the Hudson. Ten miles southwest of Kingston, at the village of High Falls, dark beds of a previously unknown limestone formation were exposed during excavation for the canal. The discovery of these natural cement beds, now recognized as part of the Rondout limestone of Silurian age, made possible the development of a natural cement industry unparalleled elsewhere in the United States. Throughout the remainder of the nineteenth century the industry was concentrated at Rosendale and Rondout. By 1892 more than a dozen major plants produced nearly 3,000,000 barrels of cement annually—90 percent of all cement consumed in the United States at that time. But just before the close of the century the introduction of the portland process caused the natural cement industry to decline and then all but disappear. Ironically, as the old quarries and kilns at Rosendale fell into disuse, the new portland cement industry thrived in northern Ulster County, where nonmagnesian, crystalline limestones of Devonian age, the Alsen and Becraft formations, as well as the Coeymans and Manlius limestones, were exploited.

The Rosendale area, nevertheless, had influenced the development of a standard section for the Silurian and Devonian systems in North America. When the four geologic districts of New York State were delimited in the 1830's, Ulster County was included in the First District, and William Mather was chosen to report on the geology of this area,

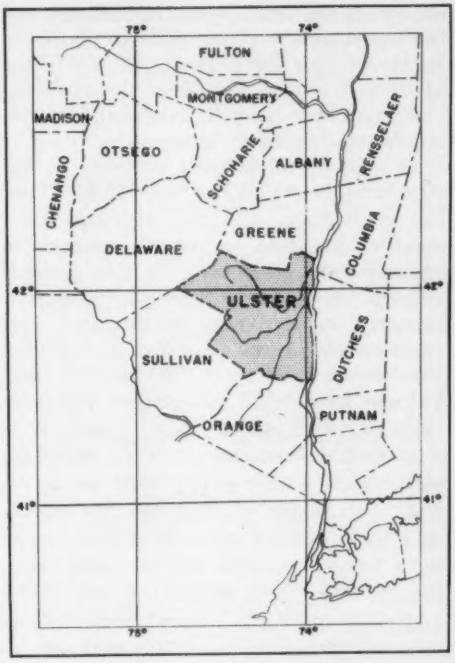


FIG. 1.—Index map of southeastern New York showing the location of Ulster County.

including the cement belt. His *Geology of the First Geological District*, published in 1843, but preceded by several preliminary reports, is the first comprehensive work concerned with the stratigraphy of Ulster County. The rocks of Mather's New York system, his classification of the Paleozoic of southeastern New York, are well displayed in the Rosendale segment of the Rondout Valley. The New York System corresponds to parts of the Devonian, Silurian, and Ordovician systems of the present day. Despite this work, the structure of the cement belt was not to be unraveled until the cement industry itself had declined after 1893. The geology of the Rondout-Whiteport-Rosendale region had drawn geologists by the score, and the stratigraphic positions of the Silurian and Devonian limestones were eventually worked out in detail by Darton, Van Ingen and Clark, Grabau, Hartnagel, and many others at the close of the century. By 1910, faunal lists had been published for

nearly all the fossiliferous formations, and the top boundary of the Silurian system in North America was drawn at the top of the Manlius limestone and below the overlying Coeymans limestone, the base of the Devonian system in Ulster County.

As commercial interest switched to the structurally complex belt between the Catskill escarpment and the Hudson River north of Kingston, so did the interests of contemporary geologists; the first geologic maps published on U. S. Geological Survey topographic base maps for this area were prepared by George Chadwick and Rudolf Ruedemann in the early 1940's for the Catskill and Kaaterskill quadrangles which include part of northern Ulster County. With a few notable exceptions, all the detailed geologic maps painstakingly done in the cement belt south of Kingston during the nineteenth century have either been lost or have never appeared on adequate topographic base maps. It was not until R. M. Logie restudied the natural cement limestones in detail in the 1930's that the internal stratigraphy of the Rondout limestone was deciphered, but this study has not been published and large-scale geologic maps of the cement belt are still lacking.

Construction of the Ashokan Reservoir and Aqueduct for the water supply system of the City of New York provided the incentive for Charles Berkey's *Geology of the New York Aqueduct*, the first work on the valleys of the upper Rondout and Esopus to use modern stratigraphic terminology and to base structural interpretations on diamond drill core measurements. It was published as a New York State Museum Bulletin in 1911. Again, technological requirements had preceded and initiated an advance in geologic techniques.

Before the 1920's, very little information was published on the Silurian Shawangunk conglomerate below the cement limestone sequence; moreover, a clear structural description of the intricately deformed Ordovician clastic rocks below the Ordovician and Silurian unconformity was unavailable. In 1929, however, Bradford Willard provided stratigraphic evidence suggesting that the Taconic disturbance occurred during the interval represented by the unconformity below the Shawangunk conglomerate; in the following year C. K. and F. M. Swartz traced the Tuscarora and Clinton units of Swatara Gap, Pa., eastward and found that they merged into the Shawangunk conglomerate at the Delaware Water Gap, and that the conglomerate continued without interruption into Ulster County. They concluded that the age of the formation was early Middle Silurian and reinforced the concept that a major hiatus exists below the base of the Silurian system in much of eastern New York.

In 1932, Charles Schuchert and Chester Longwell summarized structural and stratigraphic facts from Kingston and the Catskill cement belt, indicating at least two episodes of deformation, Taconic and Acadian, during Paleozoic time in the mid-Hudson Valley region. It became clear, indeed, that a single orogeny at the close of the Paleozoic could not have been responsible for all northern Appalachian structures and that there was a series of smaller orogenic disturbances distributed throughout Paleozoic time. It also was learned that the disturbances were possibly not correlative with similar events in Europe, Asia, and Africa.

Between 1930 and 1945, stratigraphic publications by Winifred Goldring, G. A. Cooper, Rudolf Ruedemann, Rousseau Flower, George Chadwick, and several other geologists clarified much of the older work and prepared the way for a new and more realistic understanding of the lower Paleozoic section of eastern New York.

Since 1945, synthesis and mild revision have characterized the most recent work. Detailed studies by W. A. Oliver, Jr., have enhanced our knowledge of the facies relationships of the Onondaga limestone. Various workers have divided the Shawangunk conglomerate into three or even five members. Lawrence Rickard, Jean Berdan, and other contemporary stratigraphers have new evidence that several long-recognized stratigraphic units, e.g., the Manlius and Coeymans limestones, each transgress time lines so sharply that they may actually be, at least in part, facies of each other. This new

work is reminiscent of the studies published by G. A. Cooper and George Chadwick in the 1930's in which they demonstrate the importance of facies relationships in the Middle and Upper Devonian rocks of eastern New York. If facies changes are as marked in the Lower Devonian and Silurian part of the section as in the Upper Devonian, the recognized contact between the Silurian and Devonian systems may be invalidated, i.e., the Manlius limestone may actually be the base of the Devonian system. The base of the Silurian system, the lowest member of the Shawangunk conglomerate, also may be of different age in different places, suggesting the possibility of several different ages for the Taconic orogeny even within Ulster County.

Since Ruedemann's death, however, published papers on the deformed Ordovician rocks below the Taconic unconformity in the area have been few; it is in this subject that work for the future could be most profitable.

In retrospect, the most recent work in geology in Ulster County, as elsewhere in America, indicates the need for more complete information on tectonic history as an aid to stratigraphic correlation. It suggests, moreover, the necessity for critically reviewing some of the most widely held concepts of American geology.

REFERENCES

BERKEY, C. P. *Geology of the New York Aqueduct*. New York State Mus. Bull. 146. 1911.

CHADWICK, G. H. *Revision of "the New York series."* Science, new ser., **28**: 346–348. 1908.

———. *Catskill formation*. Bull. Geol. Soc. Amer. **42**(1): 242–243. 1931.

———. *Great Catskill Delta*. Pan-Amer. Geol. **60**(2): 91–107. 1933a.

———. *Hamilton red beds in eastern New York*. Science, new ser., **77**: 86–87. 1933b.

———. *Upper Devonian of the New York region*. Bull. Geol. Soc. Amer. **44**: pt. 1: 177. 1933c.

———. *Geology of the Catskill and Kaaterskill quadrangles*. New York State Mus. Bull. 336, pt. 2. 1944.

CLARKE, J. M. *Classification of New York series of geologic formations*. New York State Mus. Handbook 19: 29 pp. 1903.

——— and SCHUCHERT, C. *The nomenclature of the New York series of geological formations*. Science, new ser., **10**: 874–878. 1899.

COOPER, G. A. *Stratigraphy of the Hamilton group of New York*. Amer. Journ. Sci., ser. 5, **19**: 116–134. 1930.

———. *Stratigraphy of the Hamilton group of eastern New York*. Amer. Journ. Sci., ser. 5, **26**: 537–551. 1934.

DARTON, N. H. *Preliminary report on the geology of Ulster County*. New York State Mus. Rep. 47. 1894.

DAVIS, W. M. *The nonconformity at Rondout, New York*. Amer. Journ. Sci., ser. 3, **26**: 389–395. 1883.

GOLDRING, W. *Geology of the Coxsackie quadrangle, New York*. New York State Mus. Bull. 332. 1943.

——— and FLOWER, R. H. *Restudy of the Schoharie and Esopus formations of New York State*. Amer. Journ. Sci. **240**: 673–694. 1942.

HARTNAGEL, C. A. *Notes on the Siluric or Ontaric section of eastern New York*. New York State Mus. Bull. 107: 39–54. 1907.

———. *Classification of the geologic formations of the State of New York*. New York State Mus. Handbook 19. 1912.

MATHER, W. W. *Geology of New York: Report on the First District*. 1843.

MENCHER, E. *Catskill facies of New York State*. Bull. Geol. Soc. Amer. **50**(11): 1761–1793. 1939.

OLIVER, W. A., JR. *Stratigraphy of the Onondaga limestone in eastern New York*. Bull. Geol. Soc. Amer. **67**: 1441–1474. 1956.

RUEDEMANN, R. *Geology of the Catskill and Kaaterskill quadrangles. Pt. 1*. New York State Mus. Bull. 331: 7–188. 1942.

SCHUCHERT, C. *Silurian formations of southeastern New York, New Jersey, and Pennsylvania*. Bull. Geol. Soc. Amer. **27**: 531–534. 1916.

——— and LONGWELL, C. R. *Paleozoic deformations of the Hudson Valley region, New York*. Amer. Journ. Sci., ser. 5, **23**: 305–326. 1932.

SWARTZ, C. K., and SWARTZ, F. M. *Silurian of the central Appalachians*. Bull. Geol. Soc. Amer. **51**(2): 148–149. 1929.

———. *Age of the Shawangunk conglomerate of eastern New York*. Amer. Journ. Sci., ser. 5, **20**: 467–474. 1930.

VAN INGEN, G., and CLARK, P. E. *Disturbed fossiliferous rocks in the vicinity of Rondout, New York*. New York State Mus. Bull. 69: 1176–1227. 1903.

WILLARD, B. *The age and origin of the Shawangunk formation*. Journ. Paleont. **1**(4): 255–258. 1928.

———. *Stratigraphic aspect of Taconic disturbance*. Pan-Amer. Geol. **51**(2): 93–96. 1929.

Remarks on the History of American Petroleum Geology

By Edgar W. Owen, *University of Texas*

These remarks do not pretend to constitute a history of petroleum geology. They are merely an attempt at a perspective which seems to have been elusive.

The year 1859 may well be considered the beginning of modern times. Petroleum activated a new period of power and maneuverability for man at the same time that Darwin's *Origin of species* freed his mind from the shackles of dogma. The Drake well at Oil Creek, Pa., was completed in August 1859, producing 25 barrels per day at a depth of 69 feet. It is generally recognized as the beginning of the oil industry, although petroleum had long been used in many parts of the world. The American origin of the industry is anomalous, as western Europe was much more industrialized and had greater familiarity with the occurrence, character, and uses of oil.

Many of the basic concepts of petroleum geology were stated during the first decade after the Drake discovery. In 1860 Henry D. Rogers noted the occurrence of gas and oil on anticlines. In the same year Alexander Winchell recognized the role of reservoir porosity. In 1861 T. Sterry Hunt and E. B. Andrews emphasized the significance of anticlines, and Andrews began working as an exploration consultant while teaching at Marietta College. H. D. Rogers in 1863 advanced a carbon-ratio theory as a criterion of oil habitats. In 1865 Hunt elaborated the anticlinal theory and Briggs explained underground fluids mechanics. These concepts are basic to petroleum geology, but their enunciation did not add up to a workable doctrine for oil exploration. E. DeGolyer has stated the case admirably: "The anticlinal theory of the first half-century of the oil industry was a speculative generalization, determined empirically upon misunderstood and inadequate data."

Organization of geological observations into a disciplined science of petroleum geology has come slowly. In 1885 I. C. White, after an important consulting job for Forest Oil Co., restated the anticlinal theory clearly enough to establish it as a guiding exploration principle, but little practical application was made of it for a quarter century. Edward Orton published classic reports on the *Oil sands of southwestern Ohio* in 1886 and on *The Trenton limestone as a source of petroleum* in 1887. M. J. Munn in 1909 made a major contribution to our understanding of the migration of oil.

Following the organization of the American Association of Petroleum Geologists and the employment of thousands of professional geologists by the oil industry, our concepts of the origin, migration, and accumulation of oil and gas advanced rapidly from 1918 to 1926. During those years hundreds of important descriptive studies were published and major contributions to the philosophy of the discipline were made by Alex. W. McCoy, E. G. Woodruff, L. F. Athy, John L. Rich, F. M. Van Tuyl, R. C. Beckstrom, R. Van A. Mills, W. H. Emmons, and others. More than 50 years after its basic principles were first stated, petroleum geology had finally grown into a fairly mature discipline, with an organic literature of comprehensive observations and usable working hypotheses.

Some of the most important later scientific milestones were: 1929, E. Russell Lloyd's exposition of the nature and role of reef limestones; 1932, Parker D. Trask's work on source sediments; 1934, W. E. Wrather and F. H. Lahee, editors, *Problems of petroleum geology*; 1927–1941, A. I. Levorsen's work on stratigraphic traps; 1942, Wallace Pratt's spacious concept of *Oil in the earth*; and 1940–1950, M. King Hubbert's studies in the mechanics of fluid movement. No major contribution to the science of geology has been the creation solely of its author. All these important works were syntheses, incorporating the observations and ideas of many other workers.

The employment of geology in petroleum exploration and exploitation has been conso-

nant with the development of the science. Although I. C. White, E. B. Andrews, and a few others were employed briefly by oil operators in the last century, the first organized geological department in the oil industry was established by E. T. Dumble for the Southern Pacific Railroad in 1897. W. W. Orcutt formed a department for Union Oil Co. of California in 1898. A. C. Veach was a full-time geologist for Houston Oil Co. in 1901 and 1902, and H. B. Goodrich did pioneer consulting work during 1899 to 1902 in many areas from New Brunswick to Texas and Mexico. In 1907 and 1908 F. G. Clapp, Ralph Arnold, W. T. Griswold, and C. A. Fisher resigned from the U. S. Geological Survey to do commercial geological wark. In 1909 several able American geologists were doing phenomenally successful work in Mexico. They were associated with Europeans who had gained experience in foreign areas, where oil companies had employed geology more actively than in the United States. By 1912 several other men were engaged in consulting practice. This tardy application of known, effective scientific techniques to the costly and hazardous operations of oil exploration and development is beyond understanding. But suddenly geology became fashionable. Most of the major American oil companies established geological departments between 1913 and 1915. These were greatly expanded in 1916 and have grown at an irregular rate ever since.

As an art, petroleum geology has responded more quickly to technological developments than to new abstract scientific concepts. Its practices and methods have undergone constant transformaiton as geologists have applied, improved, and even initiated a wide variety of new techniques. Direct surface indications were the dominant guide to oil prospecting until about 1910 and were used by geologists as well as by the wildcat drillers who scorned geology. These consisted of surface seepages, unusual topographic features, drainage anomalies, "creekology," and directional trends from known fields. Surface structure mapping was the dominant exploration method from 1910 to 1925. It had been used as early as 1883 when I. C. White surveyed with a spirit level. W. T. Griswold introduced the more efficient alidade in 1901. Every petroleum geologist who worked between 1910 and 1925 had an intimate acquaintance with the rocks on the ground and with the amiable qualities of the telescopic alidade. Unfortunately, surface mapping went into almost total disuse by the oil companies after 1925. The use of aerial photographs in the field, and laboratory photogeology, have revived some of the dignity of the surface geologist in recent years.

Petroleum geology is essentially a subsurface inquiry. J. F. Carll was studying well cuttings and plotting sample logs for the Pennsylvania Geological Survey in 1875. F. W. Minshall published cross sections of the Burning Springs anticline as early as 1878. Orton's Trenton Lime report of 1887 would be a creditable subsurface study by today's standards. But the oil companies did not begin organized subsurface work until 1917, when Alex. McCoy initiated the first program for the Empire Gas & Fuel Co. Other companies adopted the methods promptly, and core-drilling was introduced in 1919 to obtain additional subsurface information. The early emphasis was on structural attitude, and stratigraphy was mainly a means to that end. The first general recognition of the importance of subsurface stratigraphic studies resulted from the publication in 1921 of two classic papers by Fritz Aurin, Glenn Clark, and Earl Trager and by Luther White and Frank Greene. Recognition of the economic importance of stratigraphic traps resulted in rapid expansion of the studies. Since World War II several large research departments have grown up in the oil industry, and their attention has turned increasingly to stratigraphy.

The seismograph dominated petroleum exploration from its successful application on the Gulf Coastal Plain in 1924 until recent diminishing economic effectiveness has forced its more efficient integration with other geological techniques. It was introduced almost simultaneously by Alex. Deussen, L. P. Garrett, and E. DeGolyer for their respective companies, quickly followed by most other operators. The refraction

method of Mintrop was used until it was largely supplanted by the reflection method perfected by J. C. Karcher in 1926. Seismograph surveys have now covered almost every acre of prospective areas in the United States; some areas have been surveyed many times. Gravity methods have also had an important, but lesser, role. The magnetometer has had wide use for rapid reconnaissance. Many other geophysical techniques have been tried without much success, but new methods are constantly under study. Geophysical instruments are used in petroleum exploration only as tools to obtain subsurface geological data. The interpretation of their data has been left largely in the hands of the technicians, whose knowledge of geological structure and of the formations they were exploring was only rudimentary. The results of geophysical exploration have been phenomenal in spite of this costly absurdity, but continued success will be measured largely by the degree of coordination with other information.

The principal effort of the petroleum geologist has always been directed to obtaining new data on earth science. His demand for information is insatiable and often exceeds his ability to assimilate it. The most reliable source of information, as well as the ultimate test of his ideas, has always been the drilling well. He soon replaced the drillers' well logs of early days with sample logs of his own making. The rotary drilling rig, which had been introduced in the Corsicana field in 1895, gradually supplanted the cable tool rig, which had furnished him rather clean cuttings from the bottom of the hole. By 1906 the rotary had reached California and in 1918 moved into Oklahoma. It reduced drilling time of individual wells from years to days, but only the concerted efforts of many geologists, engineers, and drillers supplied the inventions of tools and techniques which converted it into a satisfactory medium for getting geological data. The core barrel in 1921, later the wire-line core barrel, the side-wall core, and the drill-stem test tool, became direct sampling devices. Use of the shale shaker, and control of drilling mud viscosity, pump pressure, and other physical factors made the cuttings more intelligible samples. Introduction on a commercial scale of Schlumberger electrical logging into the United States in 1932 began a new cycle of data collection.

Instrumental logging of wells has become universal practice, conducted simultaneously with drilling, or run at the time of completion of the well. A wide range of physical characters has been recorded directly or measured indirectly by recording the response to various induced impulses. No less than a dozen logging methods have been developed and widely applied. The resulting accumulation of accurate, detailed measurements of multiple characters in billions of feet of geological section in hundreds of thousands of deep wells has exceeded the capacity of all employed geologists, engineers, and technicians to analyze and interpret them.

Application of the acquired information to problems of petroleum exploration has required the use of many scientific procedures in addition to standard geological and geophysical field methods. Micropaleontology was first applied by E. T. Dumble in 1920. It was originally used for correlation purposes in mapping subsurface structure, but broadened into environmental and ecological studies. Macropaleontology, both invertebrate and vertebrate, has been used consistently in surface work and sparingly in subsurface. The usual orthodox petrologic methods have recently been supplemented by more sophisticated techniques which are still in an early stage of development. Late discoveries in physical chemistry have had some attention, and isotope geology has been applied to some of the broader problems of geologic dating. Almost every recent advance in geology and related sciences has found some application to petroleum geology.

The contributions of petroleum geologists to the basic science of geology have been surprisingly meager, although their informal impact on the philosophy of the science has been far greater than is usually appreciated. Several reasons account for this deficiency. The requirement for immediate economic employment of their studies usually prevents definitive completion of their work. Many of their results must remain confi-

dential until after the interest of the worker and his contact with the work have subsided. For most other scientists the literature of their science is their sharpest tool; with petroleum geologists it is the most neglected. Until recently, the bachelor's degree was considered adequate for the professional training of many petroleum geologists; it is not sufficient preparation for the science of today.

The abundance of the data which the petroleum geologists have accumulated has passed their ability to marshal it, and will require new statistical and electronic sorting techniques for satisfactory analysis. Petroleum geologists generally command a more comprehensive three-dimensional view of large segments of the earth than do any other scientists. Their detailed knowledge of the character of thick sections of the geologic column is unique. Many of their concepts are far in advance of anything published. Many of the ideas in the current geological literature relating to sedimentation, stratigraphy, structure, geologic history, and physiography look silly in the light of their information. But their neglect of effective communication has resulted in continual duplication of basic studies. No scientists are more liberal in the informal sharing of their knowledge by oral discussion, but no others have made as small contributions per capita to the literature of their science. The neglect, or even disdain, of the data of petroleum geology by geologists outside the oil industry is equally indefensible. The efficient employment of the accumulated geological information and the optimum advancement of the science await a vast improvement in the means and habits of communication. As the cost of oil finding in the United States has increased to almost prohibitive levels this need has assumed critical economic importance.

The role of the petroleum geologist has changed continually with the development of the oil industry and of the general economy. The imposition of conservation measures and State control of production during and after the depression changed petroleum exploration from a gambling game to an orderly business. The growth of many large oil operators and their tenacity in acquiring and holding leases in prospective oil territory have now made acreage acquisition the limiting factor in every new exploration campaign. Diversity of ownership in small tracts has magnified both the problems and the costs. Unitization of drilling activities, elimination of excessive drilling, and cooperation in exploration have become more pressing needs than improved technological efficiency.

The role of petroleum geologists in the building of the massive and complex modern economy has been so great as to receive general recognition. But the great impact of these men on the world's ethical climate has been little appreciated. Into the traditionally selfish morals of the marketplace has been injected the influence of thousands of men educated in an idealistic atmosphere and dedicated to scientific discipline. Most of them had become geologists because of an inherent adventurous and pioneering spirit. They entered industry at a time when operational control of most big corporations was passing into the hands of trained, professional management. Their energy and the practical experience of their active, strategic profession carried many of them quickly into positions of authority in the industrial world. Their success and that of their companies came to be as closely related to the degree of their integrity and the support and cooperation which they commanded as to their technological ability. In a single generation, under their leadership and that of other men of similar training, the United States has evolved a pattern of business ethics superior to any the world has ever seen. Although piracy and rapacity are by no means extinct, and we shall never be able to dispense with the policeman, no man today can afford ethical practices inferior to the standards of his industry or profession. There even appears the anomalous suggestion that, over the long term, self interest is best served by unselfishness. Fortunately this ethical transformation has coincided with the phenomenal growth of modern industry, if it has not in fact been largely responsible for that growth. This has come to be a day of bigness, big busi-

ness, big labor, government, science, even big universities. Great power without strong checks and balances and high ethical restraint is unendurable. But in the United States, if nowhere else yet in the world, there is hope that for the first time in history we need not be afraid of bigness for its size alone. If that hope is realized the credit will belong to the teachers of this new generation of leaders.

Columbus alleged as a reason of seeking a continent in the West, that the harmony of nature required a great tract of land in the western hemisphere, to balance the known extent of land in the eastern; and it now appears that we must estimate the native values of this broad region to redress the balance of our own judgments, and appreciate the advantages opened to the human race in this country, which is our fortunate home. The land is the appointed remedy for whatever is false and fantastic in our culture. The continent we inhabit is to be physic and food for our mind, as well as our body. The land, with its tranquillising, sanative influences, is to repair the errors of a scholastic and traditional education, and bring us into just relations with men and things.—RALPH WALDO EMERSON.

me in
ess for
ed the
is new